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Sprague, F. J.
Stokes, Anson P.

Tams, J. Frederic.
Taylor, Stevenson Pierce.
Thomas, Joseph D.
Thompson, Robert M.
Thorp, Harry W.
Toch, Henry M.
Todt, Edward G.
Tomikawa, Naoji.
Truscott, Starr.

Vanderbilt, Aaron.
Van Duzer, Louis S.
Vassileff, Dimitry.
Veit, Richard C.
Vreeland, Charles E.

Wales, Charles M.
Walker, Herbert B.
Welles, Roger, Jr.
Whitaker, F. B.
White, George A.
Whiton, Chauncey G.
Williams, Ralph D.
Williams, William E.
Winslow, John.
Wood, Henry A. W.
Wright, William L.

Young, William J. J.

JUNIORS

Allen, Walter D.

Baier, Louis A.

Carlsen, F.
Colley, G. A.
Colby, Haldwell S.
Cook, Fayette A.

Erdman, George K.

Hanson, Ralph T.
Hermanrud, Torbjorn.
Hoersch, Albert.
Holbrook, Gordon G.
Hogan, Robert L.

Kam, Joseph J.

Newton, G. A.

Pulsifer, Revere B.

Rimmer, A. Cyril.

Schmidt, John D.

Track, Frank A.

ARTICLES OF INCORPORATION

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

State of New York,
City and County of New York.

We, the subscribers, Wm. H. Webb, Chas. H. Cramp, George E. Weed, H. Taylor Gause, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, Edwin D. Morgan, George W. Quintard, Harrington Putnam and Jacob W. Miller, being persons of full age and citizens of the United States, of whom a majority—namely, William H. Webb, George E. Weed, Horace See, Edwin D. Morgan, George W. Quintard, Harrington Putnam, Frank L. Fernald, and Jacob W. Miller are citizens of and residents of and within this State, desiring to associate ourselves for scientific purposes under, and pursuant to, an Act of the State of New York providing for the incorporation of benevolent, charitable, scientific, and missionary societies, passed April 12, 1848, and the several acts amending or supplementing the same, do hereby, in accordance with the requirements thereof, certify as follows:—

First. The name of title by whch the Society shall be known in law is The Society of Naval Architects and Marine Engineers.

Second. The particular business and objects of such Society are the promotion of practical and scientific knowledge in the arts of shipbuilding and marine engineering and the allied professions, and in furtherance of this object, to hold meetings for social intercourse among its members, and the reading and discussion of professional papers, and to circulate by means of publication the knowledge thus obtained.

Third. The number of directors, trustees, or managers to manage the Society shall be seven, and shall consist of a President, a Secretary, and five Members of Council.

Fourth. The names of the trustees, directors, or managers of the Society for the first year of its existence are:—President, Clement A. Griscom; Secretary, Washington L. Capps; Members of Council, Francis T. Bowles, H. Taylor Gause, Chas. H. Loring, Lewis Nixon, Harrington Putnam.

Fifth. The business of the Society is to be conducted, and its place of business and principal office is to be located, in the City and County of New York.

In Witness Whereof we have made, signed, and acknowledged this Certificate, this 28th day of April, 1893.

WILLIAM H. WEBB.
CHAS. H. CRAMP.
H. T. GAUSE.
GEORGE E. WEED.
W. T. SAMPSON.
HORACE SEE.
F. L. FERNALD.
FRANCIS T. BOWLES.
W. L. CAPPS.
E. D. MORGAN.
GEORGE W. QUINTARD.
HARRINGTON PUTNAM.
J. W. MILLER.

City and County of New York, *ss:*

On this 28th day of April, 1893, before me personally appeared William H. Webb, Charles H. Cramp, H. Taylor Gause, George E. Weed, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, and Edwin D. Morgan, to me known and known to me to be the persons described in and who executed the foregoing certificate, and severally acknowledged to me that they executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

City and County of New York, *ss:*

On this 1st day of May, 1893, before me personally appeared George W. Quintard and Harrington Putnam, to me known and known to me to be the individuals described in and who executed the foregoing certificate, and they severally acknowledged to me that they executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

City and County of New York, *ss:*

On this 9th day of May, 1893, before me personally appeared Jacob W. Miller, to me known and known to me to be one of the individuals described in and who executed the foregoing certificate, and he duly acknowledged to me that he executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

(Endorsed.)

Upon reading the within Certificate for the Incorporation of the Society of Naval Architects and Marine Engineers, I hereby approve and consent to the incorporation thereof and the within Certificate and filing thereof, and direct that the same be filed in the office of the Clerk of the City and County of New York.

Dated New York, May 10, 1893.

Edwd. Patterson,
Justice of the Supreme Court in the State of New York in and for the City and County of New York.

CONSTITUTION AND BY-LAWS OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

Article I.

Name and Object.

1. The name of this Association shall be "The Society of Naval Architects and Marine Engineers."

2. Its object shall be the promotion of the art of shipbuilding, commercial and naval.

3. In furtherance of this object, annual meetings shall be held for the reading and discussion of appropriate papers and interchange of professional ideas, thus making it possible to combine the results of experience and research on the part of shipbuilders, marine engineers, naval officers, yachtsmen, and those skilled in producing the material from which ships are built and equipped.

Article II.

Membership.

1. The Society shall consist of Members, Associates, Juniors, Honorary Membsrs and Honorary Associates.

2. *Members.*—(1) The class of Members shall consist exclusively of Naval Architects, Marine and Mechanical Engineers, including Professors of Naval Architecture or Mechanical Engineering in colleges of established reputation.

(2) A candidate of this class must be not less than twenty-five years of age and comply with the following regulations:—He shall submit to the Council a statement showing that he has been engaged in the practise of his profession, in a responsible capacity, for at least three years, and setting forth his grounds upon which he bases his claim to membership. This statement shall be signed by three Members, who shall certify to their personal knowledge of the candidate and approval of his statement.

(3) In the case of persons not American citizens, the signatures of three Members shall be required in confirmation of their personal knowledge of the candidate's scientific attainments.

(4) If three-fourths of the Members of the Council present are in favor of the admission of the candidate, his name shall be submitted to the members of the Society at the next meeting, the voting to be by ballot, should a ballot be demanded.

3. *Associates.*—(1) The class of Associates shall consist of all persons who, by profession, occupation, or scientific attainments, are qualified to discuss the qualities of a ship.

(2) Candidates for this class shall submit to the Council a written statement of their qualifications for membership. If considered by three-fourths of the Council present duly qualified for Associate membership, their names shall be submitted to the Society at its next meeting, to be voted upon by the Members and Associates, voting to be by ballot, should a ballot be demanded.

4. The proportion of votes for deciding the election of Members and Associates shall be at least four-fifths of the number recorded.

5. *Juniors.*—(1) The class of Juniors shall consist of graduates of technical schools of established reputation, or persons who have not less than two years' practical experience in marine engine works or shipyards.

(2) Candidates must be at least eighteen years of age and certify their intention to continue in the profession and become naval architects or marine engineers.

(3) Juniors shall be eligible for transfer to the class of Members after fulfilling the necessary conditions; when they are twenty-six years of age thay shall be offered the option of being transferred to active or associate membership, if they duly qualify; but if they do not accept such offer, or do not qualify, they shall be dropped from the rolls of the Society.

(4) The admission of Juniors shall be by a favorable vote of three-fourths of the members of the Council present.

(5) Juniors shall have no voice in the government of the Society or admission of members.

6. *Honorary Members and Honorary Associates.*—The Council may elect Honorary Members and Honorary Associates, the total number not to exceed twenty-five. They shall be persons of acknowledged eminence in their profession upon whom the Council may see fit to confer an honorary distinction.

Article III.

Dues.

1. The entrance fees, payable on admission to the Society, shall be as follows:—

Members and Associates, ten dollars; Juniors, five dollars; Honorary Members and Honorary Associates, no fees.

2. The annual dues shall be as follows:—

Members and Associates, ten dollars; Juniors, five dollars; Honorary Members and Honorary Associates, no dues.

3. A member transferred from one grade to another shall pay the difference between the entrance fees of the two grades, and his annual dues shall be those of the grade to which transferred.

4. The annual contributions shall be payable in advance on the first day of January. The Secretary shall notify each member of the amount due for the ensuing year at the time of giving notice for the annual meeting. On election, each member shall pay his entrance fee and annual dues for the current year and be entitled to receive the proceedings of the annual meeting of the year during which he is elected.

5. Members and Associates can compound for all future dues and become Life Members and Life Associates, by making a single payment of two hundred dollars and signing an agreement to conform to any future amendments to the Constitution and By-Laws.

6. Members are entitled to no return of fees on severing their connection with the Society.

7. Any member whose dues are more than three months in arrears shall be notified by the Secretary. Should his dues become six months in arrears he shall be again notified by the Secretary and his rights as a member suspended. Should his dues become one year in arrears, the delinquent member shall forfeit his membership in the Society unless the Council may deem it expedient to extend the time of payment.

8. The Council may, in its discretion, temporarily suspend the annual payment of dues by any member whose circumstances have become such as to make such payment impossible, and may, under similar circumstances, remit the whole or a part of dues in arrears.

9. No name shall be entered on the rolls as Member, Associate or Junior, nor shall the privilege of membership be enjoyed until all dues shall have been paid; if the payment be delayed for more than six months from the date of election the same shall be void unless the Council otherwise direct.

10. (1) Should the expulsion of any member be judged expedient by five or more members, they must draw up and sign a proposal requesting such expulsion, delivering the same to the Secretary, to be laid before the Council.

(2) If the Council do not find reason to concur in the proposal, no entry thereof shall appear in the minutes, nor shall any public discussion thereon be permitted.

(3) If, however, the Council find the charges contained in the proposal for expulsion substantiated, the accused member shall be noticed and given an opportunity to resign. If he avails himself of this privilege, no entry shall be made on the minutes nor public discussion of the case permitted; but if he declines to resign and offers no satisfactory explanation of the charge, the whole case shall be submitted to a special meeting of the Society.

(4) If two-thirds of the members at this special meeting (provided there be not less than twenty present) vote for expulsion, the chairman of the meeting shall cause the accused to be expelled from the Society, and direct the Secretary to notify the accused of this action.

Article IV.

Officers.

1. The officers of the Society shall consist of a President, Past Presidents, Honorary Vice-Presidents, twelve Vice-Presidents, twenty-four Members of Council, and a Secretary and Treasurer.

2. Both Members and Associates are eligible for the offices of President, Vice-President, and Members of Council, but three-fourths of the Council shall be Members.

3. Prior to the date of the annual meeting of the Society of the year with which the term of the President expires, the Council shall nominate a candidate for the office of President, whose name shall be presented to the Society for election at the annual meeting. Any other candidate whose nomination, signed by at least sixty Members and Associates, shall have been submitted to the Secretary prior to the annual meeting shall also be presented. The candidate receiving the highest number of votes shall be the President for the ensuing three years. The first President under this rule shall be elected at the annual meeting in 1906 and his term of office shall begin January first, 1907. The President shall not be eligible for election as his own successor.

4. The term of office of the Vice-Presidents shall be three years. The Vice-Presidents whose terms by election now expire in 1911 and 1912 shall expire as of December 31, 1911; those whose terms now expire in 1913 and 1914 shall expire December 31, 1912; those whose terms now expire in 1915 and 1916 shall expire December 31, 1913. Beginning with the four Vice-Presidents elected for the term ending December 31, 1914, there shall be four Vice-Presidents elected each year to take the place of those whose terms expire. The Vice-Presidents to fill the vacancies occurring each year in any class shall be elected by the Council from their own membership. Retiring Vice-Presidents shall be eligible for re-election. Honorary Vice-Presidents shall be chosen from the list of Vice-Presidents who have had at least ten years' service as Vice-President. They shall be chosen at the meeting of the Council next prior to the annual general meeting of the Society and must be the unanimous choice of all Members of Council present. Not more than two Vice-Presidents may be elected Honorary Vice-Presidents in any one year.

5. The term of office of the Members of Council shall be three years. Prior to September 1 of each year the President shall appoint a Nominating Committee of five (Members and Associates both being eligible). This committee shall prepare a list of six Members and two Associate to fill the vacancies occurring in due course at the end of the year, and shall forward the same to the Secretary by September 1. This list of names shall be mailed as soon as practicable after September 1 of each year to Members and Associates. The ballots shall be returned by mail to the Secretary and canvassed at the annual meeting. When the said list of names has been sent out by the Secretary, should there be a desire on the part of Members or Associates to suggest another list of candidates for the Council, any twenty Members and Associates may unite in submitting another list to the Secretary which shall also be sent out to the membership to be considered in connection with the list already sent. In case such additional nominations are made the six Members who receive the highest number of votes shall be declared elected Members of Council and the two Associates receiving the highest

number of votes shall be declared elected Associate Members of Council, in each case for a term of three years.

6. A vacancy in the office of President shall be filled by ballot by the Council from the list of Vice-Presidents until the end of the year in which it occurs. At the annual meeting of that year a new President shall be elected for three years in the manner prescribed in paragraph 3. A vacancy in the office of Member of Council shall be filled by the Council for the unexpired portion of the term of the Member or Associate causing the vacancy.

7. The Presidents, Past Presidents and Vice-Presidents shall be *ex-officio* Members of Council.

8. The Council may hold meetings, subject to the call of the President, as often as the interests of the Society may demand.

9. At all meetings of Council, five members shall constitute a quorum.

10. The Secretary and Treasurer shall be elected annually by the Council, but may be removed at any time by a majority vote of the Council after due notice has been given.

11. The Secretary must be a Member of the Society.

Article V.

Management.

1. The President shall have general supervision over affairs of the Society, appoint special committees, and preside at the annual general meetings. He shall be *ex-officio* member of all committees.

(2) In the absence of the President, the Vice-Presidents, in the order of seniority, shall preside and perform all the duties of the President.

2. The direct management of the Society shall be vested in an Executive Committee composed of five Members of Council elected annually by the Council, the President and Secretary of the Society being *ex-officio* members of the Committee. At least three of the five elective members of the Committee shall be Members of the Society.

3. The Executive Committee shall manage the affairs of the Society in conformity with the laws under which it is incorporated, and the provisions of the Constitution. It shall direct the investment and care of the funds of the Society; make appropriations for specific purposes; arrange for the reading and publication of professional papers under such regulations as the Council may, from time to time, prescribe; take measures to advance the interests of the Society, and generally direct its affairs.

4. The Executive Committee shall make an annual report to the Society, transmitting the report of the Secretary and Treasurer and of any special committee which may have been ordered.

5. The Secretary shall be the executive officer of the Society under the immediate direction of the President and Executive Committee.

(2) He shall prepared the business for the annual meetings and record the proceedings thereof.

(3) He shall be responsible for all expenditures and certify the accuracy of all bills or vouchers upon which money has been paid, and he shall conduct the correspondence of the Socciety and keep full records of the same.

6. The Treasurer shall see that all money due the Society is collected and carefully invested in such manner as the Executive Committee may direct. If considered advisable by the Council, the duties of Treasurer may be performed by the Secretary.

7. The accounts of the Secretary and Treasurer shall be audited annually by a special committee of three Members of the Council appointed by the President of the Society.

Article VI.

Meetings.

1. There shall be at least one annual general meeting of the Society for the reading and discussion of professional papers, election of officers for the ensuing year, and transaction of such other business as may be brought before it. The time and location of this meeting shall be determined by the Council at least three months prior to the date fixed.

2. Special meetings may be called by the Executive Committee at the request of twenty members, which request shall state the purpose of the meeting. The call for such meetings shall be issued ten days in advance, and shall state the purpose thereof. At these meetings, thirty members shall constitute a quorum.

3. The Society may adopt from time to time such rules as it may think proper for the order of business at its meetings.

4. Special meetings of the Executive Committee may be held at any time subject to the call of the Chairman; and four members shall constitute a quorum for the transaction of any business that may be properly brought before the Committee.

Article VII.

Amendments.

1. Proposed amendments to this Constitution must be reduced to writing and signed by not less than ten members. They shall be forwarded to the Secretary at least ten days before the annual general meeting, and shall be immediately forwarded to the Council for its consideration. If a majority of the Council approve the proposed amendment, it shall be presented to the Society at the next ensuing general meeting for discussion; if approved by two-thirds of the members present, voting by ballot, if a ballot be demanded, it shall be adopted.

INTRODUCTORY PROCEEDINGS

TWENTIETH GENERAL MEETING OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

THURSDAY MORNING, NOVEMBER 21, 1912.

The Twentieth Annual Meeting of the Society of Naval Architects and Marine Engineers was held in the Engineering Societies Building, New York City, on Thursday and Friday, November 21 and 22, 1912.

President Stevenson Taylor called the meeting to order at 10.30 o'clock.

THE PRESIDENT:—The meeting will please come to order. We will listen to the report of the Secretary-Treasurer, which is also the report to you of the Council. The report will be distributed to you so that you can read it in detail.

THE SECRETARY:—I will read the important points to you. Regarding the membership of the Society, we came to the meeting with a total of 733 members in all grades—that was the membership on November 1, 1912.

There have been during the year, unfortunately, a very large number of deaths, which reduced our membership considerably, but the members will be interested to know that, taking account of the applications passed on by the Council, there will be added sixty-five names at this meeting. Our membership stands to-day at 798, which is a very considerable increase over the membership at the same time last year. The general status of the membership is that in the grades of Members and Associates, which, of course, are in a way our most important grades, our membership is steadily increasing, but our list of Junior Members is going down hill very rapidly. The Junior Membership class is important to the Society, as it constitutes the nucleus of the membership for promotion to the other grades, and it would be well if the members would make all possible effort to recruit that class of membership.

As regards the non-payment of dues, we are in a very good position this year. The Council paid especial attention to this matter last year and directed the Secretary to see that all members were approached very seriously on that question, because while there were a great many delinquents it was felt that this was due to lack of attention more than anything else, and the result of canvassing the members of the Society who were delinquent in the payment of dues was that we drew in a great many back accounts and greatly reduced our total outstanding dues, and that now stands at a little over $2,000, which is less than half what it has been in some previous years.

As regards the financial statement which is printed in the report, it appears that we have a cash balance in hand of some $1,800, as compared to a cash balance at the same time last year of some $800. That, on the face of it, would appear to

be a very good situation, but it must be remembered that the cash balance has been increased largely by the fact that we have collected a great many back dues, that were really owing us last year, so that we are not quite as well off as the report would appear to show, and it is misleading in that respect. In fact, the Council have been considering the finances of the Society very carefully, and we want to do all we can to increase the membership, because the only logical way to look at the Society's financial condition is that its annual expenditures should not exceed its regular annual income from the members in all grades; that is the case this year, and we hope it will be in the future. In the statement of resources and liabilities we make a very good showing. The total present worth of the Society is estimated to be approximately $22,000.

REPORT OF SECRETARY-TREASURER.

NOVEMBER 15, 1912.

To the Council of the Society of Naval Architects and Marine Engineers.

GENTLEMEN:—I have the honor to submit the following report showing the condition of the Society at the close of the fiscal year ended October 31, 1912:

The membership of the Society, November 1, 1912, was as follows:—

Class of Members.	At last report Nov. 1, 1911.	Elected November, 1911.	Promotions Juniors to Members.	Promotions Juniors to Associates.	Membership at close Annual meeting, November, 1911.	Deaths.	Resignations.	Membership Nov. 1, 1912.
Members	522	21	+12	—	555	9	10	536
Associates	160	13	—	+4	177	6	9	162
Juniors	33	7	−12	−4	24	—	3	21
Life Members	7	—	—	—	7	—	—	7
Life Associates	4	—	—	—	4	—	—	4
Honorary Members	1	—	—	—	1	—	—	1
Honorary Associates	3	—	—	—	3	1	—	2
Totals	730	41	—	—	771	16	22	733

The following delinquencies exist in the payment of dues:—

	No.	Amount.	Total.
For the year ended December 31, 1907:—			
Member	1		$10 00
For the year ended December 31, 1908:—			
Member	1		10 00
For the year ended December 31, 1909:—			
Members	4	$40 00	
Associates	2	20 00	
			60 00
For the year ended December 31, 1910:—			
Members	16	$160 00	
Associates	7	70 00	
			230 00
For the year ended December 31, 1911:—			
Members	44	$439 00	
Associates	19	190 00	
Juniors	6	30 00	
			659 00
For the year ending December 31, 1912:—			
Members	88	$880 00	
Associates	34	340 00	
Juniors	9	45 00	
			1,265 00
Total outstanding dues at October 31, 1912			$2,234 00

Deaths (16).

Past President and Honorary President (1)—
Clement A. Griscom.

Vice-Presidents (2)—
Rear-Admiral Robley D. Evans.
Rear-Admiral Geo. W. Melville.

Members (8)—
Thomas Andrews, Jr.
William W. Bates.
Walter A. Post.

Henry W. Spangler.
D. Howard Spear.
Roger P. Stebbins.
Francis H. Stillman.
J. W. Lowry Waters.

Associates (5)—
Emil L. Boas.
John C. Silva.
Samuel W. Stanton.
Samuel B. Thomas.
Howard Wood.

Resignations (22).

Members (10)—
A. V. Curtis.
Harold M. DeGraw.
Albert C. Engard.
Edward W. Hyde.
Asa M. Mattice.
Albert J. Mickley.
Stewart H. Moore.
Thomas F. Ruhm.
William H. C. Swenson.
Louis Williams.

Associates (9)—
John W. Burnham.
Carl A. Carlson.
Alvah B. Court.
Franklin J. Drake.
Adrian Gips.
Charles Kirchhoff.
Heinrich Retzmann.
Frank Schreidt.
David Wood.

Juniors (3)—
Edward O. Cutler.
Lawrence B. Chapman.
Jay D. Hammond.

FINANCIAL

Receipts.

From November 1, 1911, to October 31, 1912, inclusive.

Entrance fees of new members for the year ending December 31, 1912:—		
Members and Associates	$752 00	
Juniors	50 00	
		$802 00
Dues for the year ending December 31, 1912:		
Members and Associates	$6,030 00	
Juniors	80 00	
		6,110 00
Dues for the year ended December 31, 1911:—		
Members and Associates	$1,115 00	
Juniors	65 00	
		1,180 00
Dues for the year ended December 31, 1910:—		
Members and Associates	$150 00	
Juniors	25 00	
		175 00
Dues for the year ended December 31, 1909:—		
Members and Associates	$20 00	
Juniors	5 00	
		25 00
Membership dues paid in advance:—		
For the year ending December 31, 1913		60 00
Membership dues from suspensions		25 25
Sales of publications:—		
Society transactions to members and dealers	$1,012 59	
Special editions of papers	30 50	
		1,043 09
Exchange on checks—members' dues		16 12
Banquet—annual meeting, 1911	$1,471 25	
Annual meeting, 1912	150 00	
		1,621 25
Interest:—		
On municipal bonds, City of New York	$647 50	
On bank balances, Franklin Trust Company	22 05	
		669 55
Kelvin fund		425 50
Total receipts		$12,152 76
Balance, cash in bank and on hand, November 1, 1911		901 72
		$13,054 48

STATEMENT.

DISBURSEMENTS.

From October 31, 1911, to October 31, 1912, inclusive.

Publications:—		
Printing Volume 19	$5,250 27	
Miscellaneous printing	291 00	
Forwarding volumes, papers and membership year books	122 42	
Storage of volumes	105 60	
		$5,769 29
Rent of safe deposit box, Franklin Trust Co		5 00
Expenses 19th annual banquet, November, 1911		1,593 95
Expenses 19th annual meeting, November, 1911		450 52
Expenses 20th annual meeting, November, 1912; postage, programs, etc		30 00
Exchange of remittances, members' dues		6 16
Salaries and clerical expenses		1,380 00
Audit of books and accounts to November 1, 1911		180 00
Rent of society rooms		720 00
Office expenses, postage, stationery, etc		632 82
Kelvin fund		477 75
Total disbursements		$11,245 49
Balance cash, October 31, 1912:—		
In Franklin Trust Company	$1,805 88	
On hand	3 11	
		1,808 99
		$13,054 48

Statement of Resources and Liabilities.

RESOURCES.

Membership dues due from members after deducting for deaths and resignations ($355.00) and for doubtful accounts ($500.00)	$1,379 00
Due from dealers for volumes	570 25
Accrued interest, municipal bonds	157 50
Municipal bonds, at cost	12,560 00
Office furniture and equipment at 20 per cent reduction from cost	1,112 00
Publications on hand at 50 per cent reduction from cost, excepting Volumes 17, 18 and 19	4,528 92
Cash on deposit, Franklin Trust Company	1,805 88
Cash on hand	3 11
Total resources	$22,116 66

LIABILITIES.

Membership dues, paid in advance	$70 00	
Paid in advance, 1912 banquet	150 00	
Paid in advance for Volume 20	20 00	
Total liabilities		240 00
Society's present worth, October 31, 1912		$21,876 66

The financial statements have been verified by the Universal Audit Company of New York.

Respectfully submitted.

DANIEL H. COX,
Secretary-Treasurer.

THE PRESIDENT:—Gentlemen, you have heard the report of the Secretary-Treasurer. What is your pleasure?

On motion the report was accepted.

THE PRESIDENT:—Our next duty, gentlemen, is to have the list of the names of those who have passed away during the past year read in memoriam. Will you please rise. The Secretary-Treasurer will read the names.

The Secretary read the names of the deceased members, and during such reading the members present at the meeting stood.

THE PRESIDENT:—As you are aware, gentlemen, the term of the present president expires on December 31, and it was the business of the Council at its meeting yesterday to make a nomination for president for the ensuing term, such nomination to be submitted to you this morning. I am pleased to say that the Council appointed a nominating committee and their report was received unanimously, with enthusiasm, and Col. Robert M. Thompson is the nominee for president for the ensuing term. What is your pleasure?

NAVAL CONSTRUCTOR R. H. ROBINSON, *Member of Council:*—I move the election of Colonel Thompson as President of the Society.

NAVAL CONSTRUCTOR J. H. LINNARD, *Member of Council:*—I second the motion.

THE PRESIDENT:—It is moved and seconded that the recommendation of the Council be approved, and that Col. Robert M. Thompson be your president for the next term. Those in favor please say "Aye;" contrary-minded, "No." Carried unanimously.

I will have a little more to say on that subject later.

The Secretary will now announce the election of members in the several grades as the election now stands.

THE SECRETARY:—The following applications were passed upon favorably by the Council at its meeting yesterday afternoon:—

Members (33).

John M. Cherry, Superintendent Floating Equipment, Lehigh Valley Railroad Co., Jersey City, N. J.

Edward P. Morse, Jr., General Superintendent, Morse Dry Dock & Repair Co., Ft. 57th Street, Brooklyn, N. Y.

Charles M. Englis, Sole Proprietor of firm of Charles M. Englis, 176 Clinton Avenue, Brooklyn, N. Y.

John A. Moran, Treasurer, Atlantic Basin Iron Works, 20 Summit Street, Brooklyn, N. Y.

Thomas F. Newman, Secretary and General Manager, Cleveland & Buffalo Transit Co., Cleveland, Ohio.

Brath Lars, Assistant Chief Draughtsman, Hull Draughting Room, Fore River Shipbuilding Co., Quincy, Mass.

James L. Crandall, President and Chief Engineer, H. I. Crandall & Son Co., Boston, Mass.

James O. Gawne, Assistant Naval Constructor, U. S. Navy Bureau Construction and Repair, Navy Department, Washington, D. C.

Thomas M. Gunn, Designer and Estimator, Electric Boat Co., Groton, Conn.

Harry R. Wheeler, Secretary and Chief Engineer, Henry Steers Incorporated, 17 Battery Place, New York, N. Y.

Arthur J. Grymes, Superintendent and Manager, Marine Department, Erie Railroad Co., Hoboken, N. J.

Edward Wilding, Naval Architect, Harlan & Wolff, Belfast, Ireland.

James H. Kurtz, Chief Draughtsman, Engineering Department, Cramp's Shipyard, Philadelphia.

George B. Drake, Naval Architect, 17 Battery Place, New York, N. Y.

Charles Jackson, Chief Engineer, Marine Department, The Texas Co., 17 Battery Place, New York, N. Y.

Donald Mathieson, Superintendent Engineer and Naval Architect, W. R. Grace & Co., Hanover Square, New York, N. Y.

Henry W. Dixon, Superintending Engineer, Coast Steamship Co., 32 Broadway, New York, N. Y.

Edwin S. Alexander, Assistant to General Manager, Newport News Shipbuilding and Dry Dock Co., Newport News, Va.

William Gregory Esmond, Assistant Chief Draughtsman, Lake Torpedo Boat Co., Bridgeport, Conn.

John F. Nichols, Assistant Chief Engineer, Newport News Shipbuilding and Dry Dock Co., Newport News, Va.

Geo. Uhler, Supervising Inspector, General Steamboat Inspection Services, U. S.

Francis A. Martin, Ship and Engineer Surveyor, with Frank S. Martin, 52 Beaver Street, New York, N. Y.

David Dutrow Thomas, Chief Engine Draughtsman, Marine Department, Maryland Steel Co.

Pierce J. McAuliffe, Engineer in Charge of Construction of Hydraulic Dredges, Morris Machine Works, Baldwinsville, N. Y.

Christian Hinricks, Chief Engineer, Seattle Construction and Dry Dock Co., Seattle, Wash.

William D. Kearfott, in charge of Marine Department of Warren Steam Pump Co., of Warren, Mass.; 95 Liberty Street, New York, N. Y.

Einar L. M. Sivard, Engineer, Welin Marine Engine Co., 305 Vernon Avenue, Long Island City, N. Y.

Samuel Newton, Draughtsman, W. & A. Fletcher Co., Hoboken, N. J.

Henry N. Fletcher, Secretary of W. & A. Fletcher Co., Hoboken, N. J.

Benjamin F. Ward, Superintending Engineer, Marine Department, New York Central & Hudson River Railroad Co., 330 Central Avenue, Hoboken, N. J.

Frederick C. Lang, President, Tietjen & Lang Dry Dock Co., Hoboken, N. J.

Henry Q. Layman, Marine Engine Department, The Pusey & Jones Co., Wilmington, Del.

Hugh L. Tims, Superintendent of Shipyard, Western Shipbuilding and Dry Dock Co., Port Arthur, Ontario, Canada.

Associates (17).

Harry R. Raymond, Steamship Manager, Clyde Steamship Co., Atlantic Gulf & West Indies Steamship Co., Pier 36, North River, New York, N. Y.

William L. Chapman, Secretary, Merritt-Chapman Co., 17 Battery Place, New York, N. Y.

John M. Emery, Manager, Marine Department, Delaware, Lackawanna & Western Railroad Co., Hoboken, N. J.

Robert C. Scholz, Assistant to General Manager, New England Navigation Co., Pier 19, North River, New York, N. Y.

William H. Pleasants, Vice-President and General Manager, Ocean Steamship Co., Pier 35, North River, New York, N. Y.

Herbert B. Walker, President and General Manager, Old Dominion Steamship Co., Pier 25, North River, New York, N. Y.

Calvin Austin, President, Eastern Steamship Corporation, India Wharf, Boston, Mass.

Starr Truscott, Draughtsman, Hull Department, American Shipbuilding Co., Cleveland, Ohio.

Alexander F. Jenkins, President, The Alexander Milburn Co., Baltimore, Md.

Maximilian Burstyn, Commander, Austrian Navy, Naval Attaché, Austrian Embassy, Washington, D. C.

Alexander H. Jeffrey, Manager and Secretary, Polson Iron Works, Toronto, Canada.

William B. Robins, Draughtsman in Office of Inspector of Machinery, U. S. Navy, Cramp's Shipyard, Philadelphia, Pa.

William G. Gustafson, Draughtsman, Pusey & Jones Co., Wilmington, Del.

Reginald E. Gillmor, Mechanical and Electrical Engineer, Sperry Gyroscope Co., 74 Broadway, New York, N. Y.

Karl Boy Ed., Naval Attaché, German Embassy, Washington, D. C.

Charles A. Christoffers, Treasurer, Amalgamated Paint Co., 42 Broadway, New York, N. Y.

David C. Howard, President, DeLaney Forge & Iron Co., 300 Perry Street, Buffalo, N. Y.

Junior to Member (7).

Francis J. French, Engineer, The Jahnke Navigation Co., New Orleans, La.

Frank E. Bagger, Lieutenant, U. S. Revenue Cutter Service, Treasury Department, Washington, D. C.

Dayton, E. Herrick, Engineer, Mosher Water Tube Boiler Co., Ossining, N. Y.

Charles W. Hubbell, Production Engineer, The Seymour Manufacturing Co., Seymour, Conn.

William J. Norton, Secretary, National Electric Light Association, 429 Home Insurance Building, Chicago, Ill.

Jerome C. Hunsaker, Assistant Naval Constructor, U. S. Navy, Navy Yard, Boston, Mass.

A. de Bretteville, Manager, Main Street Iron Works, San Francisco, Cal.

Junior to Associate (1).

Harry A. Musham, Lieutenant, U. S. Army, 421 Rush Street, Chicago, Ill.

Juniors (2).

Louis A. Baier, Draughtsman, 615 East University Avenue, Ann Arbor, Mich.

Frank A. Track, Draughtsman, Lighterage Department, Standard Oil Co., 26 Broadway, New York, N. Y.

THE PRESIDENT:—A motion to ratify these elections is in order.

A MEMBER:—I move that the report be accepted and approved.

Motion put to vote and carried.

THE PRESIDENT:—The gentlemen named are declared elected as Members, Associates and Juniors, respectively.

My next duty, gentlemen, is to announce to you the following changes in the Council during the summer to fill vacancies:—Captain A. P. Niblack to be Vice-President to fill the vacancy caused by death of Rear-Admiral R. D. Evans, U. S. Navy; G. W. Dickie to be Vice-President to fill vacancy caused by death of Rear-Admiral G. W. Melville, U. S. Navy; Commander L. H. Chandler, U. S. Navy, to be Member of Council to fill vacancy caused by promotion of G. W. Dickie; Captain C. A. McAllister, U. S. Revenue Cutter Service, to be Member of Council to fill vacancy caused by death of W. A. Post; H. S. Grove to be Associate Member of Council to fill vacancy caused by the promotion of Captain Niblack.

The President also read the following announcement:—

The Council unanimously elected Naval Constructor Frank L. Fernald an Honorary Vice-President, and Mr. Lewis Nixon was elected a Vice-President to fill the place of Mr. Fernald, for the term ending December 31, 1915; and also elected Admiral H. I. Cone, Capt. A. P. Niblack, and Mr. G. E. Weed for the same term.

The result of canvass of ballots was reported as resulting in the election of the following Members of Council for the term ending December 31, 1915:—Naval Constructor W. J. Baxter, Mr. W. D. Forbes, Mr. Lewis Nixon, Commander L. H. Chandler, Mr. Andrew Fletcher, Mr. H. A. Magoun.

The promotion of Mr. Nixon to Vice-President leaves a vacancy in Member of Council which is to be filled later by the Council.

The following were elected Associate Members of Council:—Mr. John S. Hyde and Mr. Harvey D. Goulder.

Monsieur L. E. Bertin was elected an Honorary Member of the Society by the Council.

THE PRESIDENT:—I trust all of these elections meet with your approval. (Applause.)

With reference to participation in the International Congress at the Panama-Pacific Exposition in 1915, on behalf of the Council I desire to say that at yesterday's meeting, the largest and most enthusiastic one I have ever attended, the question of taking part in the International Congress to be held in connection with the Panama-Pacific Exposition in 1915 was discussed very thoroughly, and it seems that, in order to carry out that scheme, the various professional societies of this country are asked to underwrite a subscription of $40,000, $2,000 of whch is allotted to this Society. It was passed by the Council that the members of this Society be asked to contribute the sum of $5 each, that is, such of the members as may feel inclined so to do, but they have also made sure that the honor of the Society as committed to this underwriting will be fully taken care of, and I trust that when this application goes to you you will feel sufficiently interested in the Congress and in the obligation of your Society to give it the financial support asked for.

I desire to announce that the Secretary-Treasurer has been re-elected. I am quite sure that nothing better could be done by the Society than the re-election of our Secretary-Treasurer, Mr. Daniel H. Cox. (Applause.)

It is customary at this time to make a President's address. I have prepared the following.

PRESIDENT'S ADDRESS.

I welcome you to the twentieth annual meeting of The Society of Naval Architects and Marine Engineers and congratulate you on your successful career. Your numbers have more than kept pace with the growth in the number of shipyards and kindred establishments, your treasury is in good condition, and your work is entirely praiseworthy.

When we consider that on the roster of this Society there are the names of those who are responsible in one way or another for the design and construction of every important vessel and its equipment in the naval and merchant service of the United States, and feel that in all things these men, so far as opportunity is given, are advancing yearly the science of shipbuilding, we have the right to feel proud of its membership.

Our Navy has grown steadily greater, better and more efficient, and it is only necessary to have the support of our citizens to continue to do so and to hold its rightful place in the world.

Our merchant service is doing as well as it can; our shipyards are fairly busy, though it remains to be desired that there shall be so much greater demand for new ships that many new yards will be necessary.

The progress in the development of power for ships has been especially interesting during the past year. It is reported that at present there are thirty-four ships under construction abroad with Diesel oil engines, twenty-three of which range from two thousand to ten thousand tons.

High-speed turbines with comparatively low-speed efficient propellers driven by intermediate gearing are being used under several different methods of combination; and we are now awaiting with great interest the trial of the latest development, namely, the combination of turbines and electric motors which will soon be driving one of the large colliers of the United States Navy.

All of these schemes have advantages, while our aged friend, the reciprocating engine, is still doing business at the old stand, though sometimes in combination with its rival, the turbine. It will be interesting for you to study the relative advantages and disadvantages that you may determine which combination will best answer the particular purpose for which you are called upon to design ships. It seems quite clear at present that no one scheme is best for all purposes.

Some of the papers of this meeting and the discussion thereof will add to your fund of knowledge.

Important matters that have been under consideration by your Council and those that have been referred to certain committees are as follows:—The raising of an endowment fund, the income of which may be used for awarding annually medals or prizes to the younger members for professional papers of special merit and for paying extraordinary expenses that occasionally occur without using the regular income, which only now about enables us to publish our proceedings in the present high standard manner; and the advisability of changing the date of our annual meeting to nearly one month later in the year in order to enable our members from the west and Great Lakes to attend the meetings, the present time happening to be very inconvenient for them on account of business conditions existing between November 15 and December 15 each year. The committees will appreciate suggestions from the members on these matters.

It is not unusual in this address to mention those who have been taken from us by death during the year. A tribute to all of these is given by the Society in another way. During the past year, however, the Reaper has cut deep into our list of officials, and it seems fitting to call your especial attention to the memory of Melville, Post, and Griscom.

George Wallace Melville, Rear-Admiral U. S. Navy, retired, Vice-President of this Society, died March 17, 1912, seventy-one years of age. Born in the city of New York, at twenty-one he entered the service of the United States in which he remained until his death. As a subordinate during almost the entire Civil War, as chief engineer and commander in the Arctic region for several years, and as engineer-in-chief of the United States Navy from 1887 to his retirement in 1903,

during which time the then called New Navy was largely designed and constructed, he always served his country and his fellow-man with distinction and honor. He served this Society as Vice-President since its organization and contributed much to its welfare by his contributions to the proceedings and by his influence. A rugged character and a staunch friend. As has been well said in one of his best biographies, "As an officer and as an engineer, the gospel of his life to the very last was 'Work'—he asked nothing from his subordinates which he did not give himself."

Walter A. Post died February 12, 1912, aged fifty-five years. He served this Society as Member of Council from the annual meeting of 1900 until the time of his death. His ability fully warranted his promotion a few years ago to the presidency of one of the most prominent shipyards of this country. His counsel, always given with his modest, rather retiring manner, endeared him to his fellow members, who with his other numerous friends mourn his sudden death.

Clement Acton Griscom, Past President, who died November 10, 1912, in his seventy-second year, was one of the founders of this Society and its first president, which office he held for ten successive years. Entering in early life the office of a shipping firm, he became one of the most prominent men in marine affairs in this country. He ardently hoped for a full restoration of the American merchant marine, and at one period dared to dream of seeing the flag flying over the seas of the world. His interest in this Society, his influence in its development, his charming, genial manner, and his encouraging words to all will long be remembered.

The American merchant marine has always been one subject that your presidents have felt called upon to mention in their addresses. I thought last year that I would not venture again to speak on that topic, but recent action of Congress and recent action of the people at the polls impel me to say a few words.

One is tempted to quote Shakespeare's Richard III, using but the first half of the sentence, and say, "Now is the Winter of our discontent. * * *"

The party so long in office has accomplished nothing unless it be possible that the riders forced upon the act governing the management of the Panama Canal can really be in any way construed to be advantageous. The President-elect in his letter of acceptance of his nomination gave us some ringing sentences like these: "Without a great merchant marine we cannot take our rightful place in the commerce of the world;" "It would be a little ridiculous if we should build it (the Panama Canal) and have no ships to send through it," and his conclusion is, "That we must build and buy ships in competition with the world. We can do it if we but give ourselves leave."

It is not to be expected that a candidate in his letter of acceptance covering so many important issues would foretell how soon we can build ships in competition with the world, or if we bought ships abroad how we may run them in competition with the world, even with a modified tariff, any more than the President in the midst of an important political campaign can be expected to justify the signing of a Panama Canal act with riders containing legislation not germane to the subject of the act, being thus quite inconsistent with his own previous action on another act.

It is easy to cry "We cannot build ships as cheaply as abroad; alter our registry laws and let us buy our ships where we will," but the fact still remains that we cannot run such ships in competition with the world until many other demands of our laws, times and usages have been considerably modified.

Perhaps the party soon to come in power with its distinguished leader may with new tariffs produce results under which we may build, buy and run ships in competition with the world, and thus construct a merchant marine worthy of this great country. Such adjustment of tariffs will be pretty near complete free trade, and our country may be happy under the new conditions. Having always been a protectionist with no special interest, with only the interest of the whole country at heart, I have grave doubts which are only increased by observation of free-trade countries abroad. We must still be patient. It is evident that the President-elect recognizes the existing situation of our merchant marine, but I feel on this subject like quoting again—this time a modern poet:—

> "Behold! We know not anything
> We can but trust that good shall fall
> At last—*far off*—at last to all
> And every Winter change to Spring."

The one overwhelming event of the year which more than any other directly interests naval architects and marine engineers, was the loss in April last, with its awful consequences, of the splendid Titanic, the latest work of one of the great shipbuilding yards of the world.

No previous disaster at sea, great as some have been, ever produced the consternation and appalling feeling of man's impotence than was caused by the foundering of what was considered the last word in ocean steamship construction.

The terrible event has been the occasion of investigation at home and abroad with sundry conclusions as to the responsibility for the disaster and the need of changes in the various requirements for the future. You are aware of all that has been said and done, for a matter of such vital interest to everybody must have received from every member of this Society the closest attention and most careful consideration. You have perhaps attributed the disaster to a combination of circumstances never happening before, in which combination occurs human judgment upon which, in all walks of life, in all spheres of action, so much must depend.

It is not our purpose now to sit in judgment. That particular combination may never occur again, and as Associate-Member Herbert L. Satterlee, in his "An April Crossing" published last June, safely says, "The human brain cannot compute the combinations of circumstances or unusual or extraordinary conditions that may occur on the great ocean. Man may avoid many dangers, he can multiply the means of safety and methods of rescue, but he cannot annihilate the 'peril of the sea.'"

True we cannot annihilate the peril of the sea, and we must depend in crises on human judgment. There remains for the men of our professions all the greater responsibility to make our work safe.

Since the loss of the Titanic, much stress has been laid upon the need of more lifeboats, and more life rafts. Indeed, as the laws now stand, it is quite within probability that there may be more lifeboats and rafts than can be properly and quickly handled in time of trouble.

I have frequently gazed upon the great steamers that now cross the sea and then turned to look at the lifeboats. The thought that at any time one should be compelled, by stress of weather or accident, to leave the ship and put off for safety in the comparatively tiny lifeboat seemed rather absurd. It is infinitely more important to make the steamer itself safe than to depend upon the lifeboat, or, at worst, upon the life raft. We must build our ships so subdivided by decks and water-tight bulkheads—without doors where possible—that even an injury like the Titanic's would not cause her to founder.

Further, we must be sure that the plating shall always have such ductility that ruptures in case of severe indentation shall be reduced to the minimum.

Do not infer that the plating of the Titanic was not of this character. Of this I have no knowledge and it is rather certain that no plating could withstand the shock caused by such a mass, traveling at so great a speed, coming in contact with a mountain; but we have seen plating so broken by collisions that warrants the statement that sufficient care has not always been taken in the quality of plating used on ships.

It will be impossible at all times to make bulkheads and decks as indicated, for such a demand faithfully executed might destroy the earning power of the ship; but there are many conditions that can be made better, and we must do what we can in designs and construction, educating owners if need be, to at least closely approach the desired absolute safety, safety in spite of the possible fallibility of that human judgment which cannot be—and should not be—entirely eliminated.

One more word in reference to the Titanic—a tribute to those in the engine-rooms at the time of the disaster. In our work we meet and know this class of men. Far below in the depths of the ship they well knew, long before those on deck, of the fatal hurt the ship had received. Of those directly employed by the steamship company who were called to their places as a matter of regular duty; and of those on assumed duty in behalf of the builders who were at the time in no way responsible for the management of the ship, not one was saved. There were many glorious examples of heroism on deck, but none more glorious, none showing greater self-sacrifice than the examples given by that splendid engineer corps, remaining below, awaiting the end without the slightest possible chance of life. All honor to those true brave men!

You have just elected as your president for the next term Col. Robert M. Thompson, a gentleman well and favorably known the country over as a man of great public spirit, evidenced continually by his interest in affairs national and international, and whom to know is to respect and honor. I tender him and the Society my congratulations. He can still widen the results of his public efforts, and the Society has secured a most admirable presiding officer, who will carefully watch its interests.

Not until December thirty-first next will my term of office as your president expire, but practically the duties will terminate with this meeting. The Council and certain other very partial friends have been kind enough to express the wish that I might continue in this office, but I firmly believe and trust that you do—that it is a very wise provision of our constitution that "the President shall not be eligible for election as his own successor."

Though, as I have said, my duties continue until the end of the year, this is the time and place for me to acknowledge with gratitude the great honor you conferred upon me three years ago, an honor unsolicited and unexpected, an honor which, coming from a professional society of your importance, is the highest that can be conferred upon one by his associates.

I said on accepting the office that it would be my privilege to serve. I have not succeeded in accomplishing all of the things I hoped for. I fear no man with a proper desire for achievement ever quite does this, but I have tried to serve you well, have enjoyed the work and its attendant associations and have always received the utmost support of your Council. I can ask no more. I thank you one and all. I will always bear the kindest and most tender thoughts for The Society of Naval Architects and Marine Engineers.

The President:—The reading of the papers is now in order, and I ask your attention to the first paper, "Experiments on the Fulton and the Froude," by Prof. C. H. Peabody, Member of Council.

EXPERIMENTS ON THE FULTON AND THE FROUDE.

By Professor C. H. Peabody, Member of Council.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

PRELIMINARY.

The objects of the experiments related in this paper are the investigation of the characteristics of tow-boats and the determination of favorable conditions. The applicability of steamboats for towing was so evident that forms and proportions were settled early in the history of steam navigation, being controlled, in part, by the ideas then prevalent concerning the action of screw-propellers and in part by the conditions of service which required simplicity and reliability in the hands of men economically available for boats of that class. The conditions of the service favor conservatism, and consequently the early types have been generally preserved, though there are instances of progressive designs that have broken away from tradition, especially for large seagoing tow-boats. The propellers used for tow-boats have habitually been four-bladed, with large area and wide tips, and have had a large pitch-ratio, commonly from 1.3 to 1.5. The pitch-ratio is controlled by the use of relatively slow engines, and the form of blade according to the old ideas concerning the action of screw-propellers, especially as applied to towing. Many designers have been of the opinion that both width of blade and pitch-ratio could advantageously be reduced and, when circumstances appeared favorable, have made such changes.

During the experiments made in the summer of 1911 on the Froude with propellers having various pitch-ratios and widths of blades, advantage was taken of the opportunities to make experiments in towing and pulling; these experiments could not be reduced in time for presentation with other results, which is not to be regretted, as they can conveniently be presented here in connection with experiments on the Fulton, which is a typical harbor tow-boat made to one-third the size of its prototype the Sotoyomo, for which data are given by Naval Constructor D. W. Taylor, U. S. N., in the fifteenth volume of our Transactions. Speed trials were made of the Sotoyomo in 1907 near Mare Island Navy Yard, the model was towed in the Model Basin, and results of these investigations have been kindly furnished to me by the Chief Constructor, Admiral R. M. Watt, U. S. N.

The principal dimensions of the Sotoyomo, the Manning, and the Sonoma (a new ocean tow-boat for the Navy) are given for convenience in the following table. The Manning is given because it is the prototype of the Froude, and the Sonoma for comparison with the Manning, which has characteristics not unlike an ocean tow-boat. Thus we have, in the Fulton and the Froude, little tow-boats of the two principal types.

	Length L. W. L.	Beam.	Mean draught.	Displacement.	Speed, knots.
Sotoyomo	92.7	21	9.16	258*	10.5
Manning	188	32	12.3	1,000*	16
Sonoma	175	34	12.5	1,100*	14
Fulton	30.9	7	3.25	9.6†	6.4
Froude	37.6	6.4	2.52	8†	7.2

*Salt water. †Fresh water.

The lines of the Manning and the Froude are given in the paper of last year and need not be repeated here. The characteristics of the experimental propellers are given here for convenient reference.

PROPELLERS FOR THE FROUDE, 1911.

	Pitch ratio.	*Projected area-ratio.*
No. 1	0.8	0.61
No. 1A	0.8	0.50
No. 1B	0.8	0.44
No. 2	1.1	0.59
No. 2A	1.1	0.52
No. 2B	1.1	0.45
No. 3	1.5	0.60
No. 3A	1.5	0.53
No. 3B	1.5	0.44

These propellers all had oval blades with sharp edges and were correctly planed.

The lines of the Fulton are given in Plate 1; they are substantially the same as those of the Sotoyomo. The three experimental propellers had the following characteristics.

PROPELLERS FOR THE FULTON, 1912.

	Pitch-ratio.	*Projected area-ratio.*
No. 1	0.8	0.56
No. 2	1.0	0.53
No. 3	1.29	0.48

The propeller No. 3 was a close copy to one-third the size of the propeller of the Sotoyomo—which is represented by Plate 2, made from a drawing kindly furnished by Admiral H. I. Cone, U. S. N.—with the exception that the propellers of the Fulton had no rake. All the propellers were cast and had the surfaces smoothed but not planed; as is customary for such propellers there was some thickness near the edge which was rounded on the back to the edge. The propellers, which were made by the Hyde Windlass Company of Bath, Maine, were closely correct to pitch; the pitch-ratios are so nearly correct that variations can have little, if any, effect on our results.

The hull of the Fulton was built in the shops of the Massachusetts Institute of Technology; it had double sawed oak frames spaced 15 inches apart, oak keel, keelson, stem, stern-post, and beams, and was single-planked with $\frac{7}{8}$-inch white cedar. The construction and general arrangement are shown by Plate 3.- Measurement after construction showed that the form was fair and true to the lines. In order to reduce wind resistance the boat was practically flush-decked, the midships being covered with light hatches that could be opened for convenience in installing and running the machinery. The boat was maneuvered from a cock-pit forward and was very handy under our system of indirect electric propulsion.

The machinery and apparatus used on the Froude in 1911 were transferred to the Fulton and do not require description beyond that given in the former paper.

The tow-rope pull in both years was taken by the vertical arm of a bent lever; the horizontal arm of the lever pulled directly on a good spring balance, a dash pot being used to reduce vibration. This device was found to be convenient and as delicate as conditions warranted. The points for a series of tests came on a fair curve and appeared to have an error of not more than one per cent.

During the experiments of 1911 the Froude towed a drag made of three railroad ties bolted together in a triangle and towed from the apex. During the experiments of 1912 the Fulton towed the Froude, which had a plank bolted across the stern to augment its resistance. The drag used in 1911 was

effective, towed steadily and was not affected by wind action; it was very inconvenient, especially during turns. The Froude was considered to tow more like a barge, and with a steersman aboard was more convenient; it was affected by wind resistance.

The construction of the Fulton was deferred and the completion and equipment were delayed for various reasons so that we were ready for service only on the twenty-second of July. Our previous experience, however, enabled us to begin experiments promptly and to make most of the weather conditions, which had to be chosen advantageously, especially as the wind effect is most pronounced at slow speeds, as during towing. On the whole the weather was propitious and much work was done during the middle of the day though there was no hesitation in using early daylight, beginning at four o'clock, in order to get favorable conditions. Now that the land abreast of which our course is laid out belongs to the Massachusetts Institute of Technology we may hereafter be able to set up range lights and make our experiments late in the evening when weather conditions are commonly favorable.

Considering the long time required for a towing test over a measured course, especially for the turns, and the desirability of being able to choose sheltered parts of the basin, we decided to try measuring speed by a propeller log set forward of the boat. The propeller was 8 inches in diameter, had a pitch of 14 inches, and 3 blades. It was carried by a vertical rod supported by an outrigger above water, had its axis 9 inches below the surface, and was set 8 feet forward from the stem of the boat. Trials of this log with the Fulton running free over the measured course indicated that this log would give satisfactory results; in use, especially when there was some wind, it appears to have been influenced by surface drift, and in consequence the determination of speed on the towing tests is affected by errors that may be two or two and a half per cent. This is indicated by the dispersion of points for a curve and by check runs over the measured course. This use of the log during towing was the only divergence from tests of the two preceding years.

The writer gave personal attention to the building, preparation and experiments of the summer and occasionally took part in them, but, as in previous years, the boat was commanded by Prof. H. A. Everett, with Mr. R. B. Pulsifer for assistant. Mr. H. H. W. Keith, instructor in naval architecture, served as computor, reducing results of tests as fast as possible to serve as a guide for the prosecution of the work. On occasion he assisted also in the preparation and prosecution of the experiments. Our force included a mechanic and, for part of the time, a boy, not to mention the several mechanicians who worked on the "installation" of the machinery. It will be seen that making experiments of this nature is a serious business.

The success of the season's work is largely due to the experience, ability and devotion of Professor Everett; to Mr. Keith is due the computation and presentation of the results, for which his previous experience peculiarly fitted him; Mr. Pulsifer at all times gave loyal and intelligent assistance.

The possibility of the prosecution of experiments during the present year was due primarily to Mr. Arthur Curtiss James and Mr. Clinton H. Crane, who guaranteed a sum which I estimated as sufficient; when it was found that this sum would be much exceeded Mr. Wm. Endicott, Jr., and Mr. Henry A. Morss advanced sums which covered the remainder of the expenditures. Mr. Harrison Loring, Jr., of the R. S. Brine Transportation Co., very kindly sent a receipted bill for the transportation and launching of the Fulton and other services.

INFLUENCE OF BLADE-AREA.

A tow-boat, especially of the harbor type, has three various kinds of duty, namely (1) to run free, passing from place to place, and perhaps seeking business in face of competition; (2) towing at a reduced speed, commonly at half speed or somewhat more; and (3) pulling or pushing a ship into her berth at very slow speed, or nearly without speed.

Running-free tow-boats differ from other classes only in that being high-powered to enable them to tow, they have relatively high speed even though not designed with that in view.

To have a ready standard of comparison in our discussion of the effect of width of blade and area-ratio, let us consider that the standard admiralty blade proposed by Froude has been found sufficient for all classes of ships (excepting tow-boats), until cavitation has brought about the use of wide blades in certain cases. Now this standard blade has a maximum developed width of 0.2 of the diameter of the propeller which gives a developed area-ratio for four blades of 0.36; the projected area-ratio is somewhat less, depending on the pitch. The experiments on model propellers by Naval Constructor Taylor show that such an area-ratio is preferable for the generality of propellers but that the ratio may be increased up to 0.48 without appreciable disadvantage. From a study of Mr. Taylor's experiments and of the tests about to be related I am ready to advise the use of a projected area-ratio of about 0.5 for four-bladed propellers for all tow-boats. The minimum area-ratio of the propellers used on the Froude in 1911, as stated on page 2, is 0.44.

In considering the effect of width of blade and projected area-ratio let us take up the results of experiments on the Froude with the several pro-

pellers given in the table on page 2, for each of the three several duties of a tow-boat, namely, running free, towing, and pulling (or pushing).

For running free we may refer to Plates 47, 48, and 49 of volume 19 of the Transactions, which give the results of tests as reported last year with the propellers given on page 2 of this paper. A reference to those plates will show that the curves of power on speed for a given pitch-ratio and for all projected area-ratios from 0.44 to 0.60 are practically identical; the several curves for the various areas can be distinguished but the separation is no more that must be attributed to the unavoidable error of experiment. This result is unexpected because the increase of area-ratio for the experimental propellers of Mr. Taylor is accompanied by a loss of efficiency amounting to three or four per cent out of sixty to sixty-six per cent.

The effect of area on towing is shown by Plate 4, which gives all the points representing the separate runs and also mean curves, with brake horse-power plotted on speed. Points for tests with the original width of blade are represented by triangles, the intermediate widths have crosses, and the least widths have circles. For the pitch-ratios 0.8 and 1.1 all points lie on or closely adjacent to the curves; for the pitch-ratio 1.5 the points show a little dispersion. It would be possible to draw three separate curves for this pitch-ratio of 1.5, and in that case the curve for the least area-ratio (0.44) would lie the lowest and indicate a slight advantage for the narrower blade. In reading these diagrams, which for convenience are put on one plate, it will be noted that there are three base-lines selected so as to separate the curves for the several pitch-ratios.

On Plate 5, the results of our measurements of thrust of the propeller-shaft are plotted in the same manner as the power. These results are quoted because they represent a direct measurement in which we have great confidence, and as the points and curves have the same characteristics as those for power on Plate 4 they give direct evidence of the reliability of our power curves.

For our pulling experiments the Froude was secured by a line from our weighing-beam to a pile of the draw of the Harvard Bridge. The motor was allowed to run at various powers and the tow-line pull was read directly on the spring-balance, allowing, of course, for the inequality of the arms. The results are shown by Plate 6, for the original area-ratio of about 0.6 only; similar experiments with narrower blades were not made, partly because of lack of time and partly because their importance was not realized. The experiments gave no indication of breaking of the propeller race except at high powers for the largest pitch-ratio.

From these experiments the conclusion to my mind is direct and positive,

namely, that the width of blade and the projected area-ratio of a propeller have little or no influence on the performance of a tow-boat when (1) running free, or (2) towing. The evidence with regard to pulling is incomplete, but I believe that with a pitch-ratio not greater than 1.3, a moderate area-ratio will avoid breaking the race. It is to be borne in mind that our least area-ratio is 0.44, which is nearly a fourth greater than the developed area-ratio that has been found sufficient for general service.

This conclusion, if accepted, has a wide importance because it indicates that the best propellers for tow-boats have a well-rounded or oval blade and a moderate width. There appears, therefore, to be no reason for retaining the traditional tow-boat propeller with its excessive area and wide-tipped blades, more especially as Froude's recent experiments show that such wide-tipped propellers are about three per cent less efficient than well-rounded blades.

This separate, preliminary investigation of the effect of blade area (or rather of its ineffectiveness) clears the field and allows us from now on to concentration on other elements which have determining effects.

EXPERIMENTS ON THE FULTON, 1912.

Three types of experiments were made this year on the Fulton: (1) running free, (2) towing at various speeds up to about 0.6 full speed, and (3) pulling, both going ahead and backing. Three propellers were used, all of which had very nearly the same projected contours as the Sotoyomo propeller as shown on Plate 2.

In order to present the quality of our work and the regularity of results obtained, an individual diagram for each type is given by Plates 7, 8 and 9 with all the points representing separate experiments as well as with fair curves. Thus Plate 7 shows curves of speed, propeller thrust and brake horse-power, all plotted on revolutions of the propeller. For both speed and thrust there are curves with and against the wind; the power for a given setting of the machinery is not appreciably affected by the wind under the favorable conditions selected for experiment, and only one curve is drawn. On this plate the power is the input to the motor in kilowatts which is afterwards corrected by comparison with our brake tests to given brake horse-power as used in the other plates. It may be claimed that the regularity and distribution of points for these experiments leave little to be desired, and a comparison with standardization of full-sized ships in a tideway under such weather conditions as may chance to be experienced will lead us to wonder that such tests are as good as they are, rather than that they are not more nearly what we would desire.

Plate 8 gives for one of our series of towing experiments individual points and curves showing speed, power, propeller thrust, and tow-line pull, all plotted on revolutions of the propeller. The curves of thrust and power call for little comment unless we notice that the greater apparent dispersion of points is partly due to the fact that wind had relatively larger effort on account of slower speed.

As was explained in the preliminary statement the speeds during towing were measured by a little propeller 8 inches in diameter and with 14 inches pitch, which was carried by a bow outrigger so that its axis was 9 inches below the water level and 8 feet in front of the stem of the boat. Though this propeller log showed good results on special runs without a tow over the measured course, its operation during towing was less satisfactory, chiefly because as the season advanced we found it necessary to accept weather conditions less favorable than we would like, trying to minimize wind influence by choosing sheltered parts of the basin. Several runs were made in succession with the wind, followed by others against the wind. In drawing the fair curves greater weight was given to points which our records indicated as more reliable, and especially to points favored by shelter or other weather conditions. If two points which are apparently rather wide from the speed curve, and which we believe to be erratic, are neglected, the dispersion of points indicates that the probable error of speed measurement of a single test may be as large as four per cent, but we believe that the mean curve is much nearer the truth and we desire to claim a precision of two per cent, which, after all, is not unfavorable considering that towing is at low speed. The dispersion of the points showing thrust and pull on tow-line is a direct consequence of the uncertainty of speed.

Plate 9 shows points and curves of pulling tests with the tow-line secured to a pile of Harvard Bridge. Going ahead the weigh-beam was set up astern, but in backing it was set up near the bow. All these runs were made readily and in particular there was no indication that the race from the propeller had any tendency to break. Our thrust mechanism did not allow of measurements while backing. It must be admitted that the points and curves leave little to be desired and that the records can be accepted without reservation.

Certain subsidiary experiments will be reserved for future discussion to avoid confusion.

RUNNING FREE.

The performance of tow-boats of the ocean-going and harbor type may be discerned from Plates 47 and 49 of volume 15 of the Transactions and from Plate 9 of this paper.

As was pointed out in last year's paper the propeller with maximum pitch-ratio (1.5) as used for towing on the Froude had a small clearance from the fair-water on the stern-post and consequently it demanded a disproportionate power. This does not affect our discussion of the effect of area-ratio, but throws it out of line the discussion of the effect of pitch-ratio. Comparing, now, the other two propellers having pitch-ratios of 1.1 and 0.8, it appears that at 7 knots speed they required respectively 8.3 and 8.5 brake horse-power; this result may be attributed directly to the poorer efficiency of the low-pitch wheel, with only the reservation that experiments on propellers would lead us to expect a somewhat larger disadvantage.

The running trials on the Fulton, shown on Plate 10, indicate quite clearly the disadvantage of a small pitch-ratio which is associated with a poorer propeller efficiency; thus the propellers with pitch-ratios of 1.3, 1.0, and 0.8, at 6.5 knots, require 10.7, 10.9, and 11.5 brake horse-power respectively, or, inverting the comparison, with 11 horse-power propellers with those pitch-ratios would give the Fulton speeds of 6.55, 6.51, or 6.37 knots per hour. The difference, though not large, might be important in getting a tow away from a competitor.

On the same plate there are shown curves of propeller thrust for the two propellers with lower pitches; for the pitch-ratio of 1.3 only the upper end of the curve appears as the lower part was not properly recorded by our thrust mechanism. These curves are quoted and also the resistance (as determined by the theory of mechanical similitude) from the towing of the Sotoyomo's model at Washington.

TOWING.

The performances of ocean-going and harbor tow-boats towing at full power and at about 0.6 full speed are shown by Plates 4 and 11. Plate 11, which represents results of experiments on the Fulton, shows a small advantage for the low-pitch propeller. Plate 4 shows a corresponding advantage for a propeller of the Froude with a pitch-ratio of 0.8 as compared with one having the pitch-ratio 1.1; the coarse pitch propeller with a ratio of 1.5 appears to be at a great disadvantage, but I mistrust that this is to be attributed in part to a defective clearance from the stern-post as already indicated; such a pitch-ratio is not fitted for an ocean-going tug and the importance of the comparison is therefore diminished in consequence.

Plate 11 shows also the propeller thrust and the pull on the tow-rope measured by our weigh-beam, which are given as a matter of interest. The curious inversion of order of the thrust curves is yet to be explained.

It is to be noted that runs at less than about 0.6 full speed are with reduced power; they are most interesting experimentally, especially as the sequence of the points allows us to locate the curves certainly. A very important series which we have not attempted to run is to vary the speed at full power by increasing the resistance of the tow. Such a series of experiments, with the time required for adjusting resistance to speed, might profitably occupy a summer's work.

PULLING.

The collected result of experiments on pulling against a fixed point with one hundred per cent slip of the propeller are shown by Plate 6 for the Froude and by Plate 12 for the Fulton; the latter was tried pulling both ahead and astern.

On both the Froude and the Fulton propellers with smaller pitches gave better results pulling ahead. On the Froude the advantage of the small-pitch propeller was very striking; thus, at 7 brake horse-power the pulls for the propellers having pitch-ratios of 0.8, 1.1, and 1.5 were 400, 350, and 300 pounds. On the Fulton the smaller pitch showed an advantage but by no means so notable; thus, at 11 brake horse-power the propellers having the pitch-ratios 0.8, 1.0, and 1.3 gave the pulls 560, 545, and 490.

LENGTH OF TOW-LINE.

For all the experiments thus far recorded the length of the tow-line was constant, being 80 feet when the Froude was towing and 70 feet for the Fulton. On Plates 13 and 14 results of experiments on the Fulton with varying lengths of tow-line are shown; it will be noted that these propellers having pitch-ratios of 0.8 and 1.3 gave substantially the same results, as indeed might be expected since the question under consideration is the effect of the race of the propeller on the resistance of the tow.

The most interesting feature of these results is the effect of length of line on speed; the changes being small are to some extent covered up by the lack of accuracy of our bow-log for measuring speed; nevertheless there appears to be a substantial advantage from use of a long line which is best brought out on Plate 13. Bearing in mind that the Fulton is 30 feet long there is a gain of about ten per cent in speed due to lengthening the line from twice the length of the tow-boat to six and a half times the length. In this comparison the pull on the tow-line gives the most positive indication of the advantage of a long line; this confirms the result just quoted in terms of speed as the pull diminishes about ten per cent.

TOWING ABREAST.

In a seaway ships and barges are always towed with considerable length of line for obvious reasons; in smooth, restricted waters the tow-boat is commonly brought alongside. On Plate 15 curves are shown with the Fulton towing with an 80-foot line (less than three times its length), and towing abreast. There is an advantage of ten or twelve per cent when towing abreast, which is about the advantage of using a long tow-line (six or seven lengths). The common practice of either using a long line or towing abreast appears to be well founded.

DESIGNING.

The most practical use that can be made of the results of these tests on towing is for the design of new boats. Fortunately both the Manning and the Sotoyomo are well designed, having good forms and fair lines. Perhaps the Manning is a little too fine for an ocean tow-boat, which is likely to be rather shorter and more beamy; the form of the Sotoyomo appears to be exceptionally good for speed and might well be taken as a type for design except where speed is of minor importance, in which case a fuller body might enable a boat to carry more power.

It may therefore be suggested that designs for tow-boats shall be based directly on the tests of the Froude and the Fulton by the theory of mechanical similitude, bearing in mind that the experiments were all made in fresh water. The usual method of assuming resistance and power to be proportional to the density can be used in applying our results to boats operating on salt water.

Our results are given in brake horse-power, while engines are habitually designed for indicated power. My own opinion is that a mechanical efficiency of 0.90 may be obtained for a well-built engine when in good condition; 0.85 may be used by those who wish to be conservative.

Plate 10 shows that tow-boats are likely to be driven well up to the critical speed at which the power increases more rapidly than the cube of the speed; consequently the common method of using an admiralty coefficient for estimating power is, in my opinion, entirely inapplicable.

The speed for towing (about 0.6 full speed) is well under the critical speeds and our experiments show that power varies nearly as the cube of the speed and consequently the method of the admiralty coefficient may properly be used.

It is therefore proposed that tow-boats shall be powered for towing at a speed-length ratio of 0.6 to 0.7 by the equation

$$\text{I. H. P.} = \frac{D^{2/3} V^3}{K},$$

where D is the displacement in tons (2,240 pounds), V is the speed in knots per hour, and L is the length on water-line in feet, while K is the admiralty coefficient. The speed-length ratio is computed by the formula—

$$\frac{V}{\sqrt{L}}.$$

The speed-length ratio of the Froude when towing at $3\frac{3}{4}$ knots was 0.6 and the admiralty coefficient corresponding is 21. The Fulton when towing at $3\frac{3}{4}$ knots had a speed-length ratio of 0.67, and for it the admiralty coefficient is 22.5.

Having determined the power for towing at a given speed, the speed running free may be investigated or we may simply accept what we get; especially at or near the critical speed it takes a large increase in power to affect the speed appreciably.

To complete the design requires the determination of the proper size and proportions of the propeller. Through the courtesy of the Chief Constructor, Admiral R. M. Watt, U. S. N., tests of models of our propellers for the Fulton have been made with large slips required for towing, by Naval Constructor Taylor. From these tests and from our own data on thrust I hope to be able to present an analysis of this matter at some future time.

DISCUSSION.

Mr. John Reid, *Member:*—I think the principal charm of this paper is in the practical applications which Professor Peabody has scattered all through it, and the only reason that I am before you is that I think his conclusions are sometimes erroneous. I would like particularly to call attention to one extraordinary statement which he has made, and that is that from his experience with these experiments, the internal-combustion engine, with its high revolutions, can be fitted into a tug, and that the consequent high revolutions of the propeller would have very little effect upon the efficiency of the boat as a tug. I have had a little experience with that in the last twelve months, and I can inform Professor Peabody, so far as my

experience goes, I do not agree with his deductions. It all depends on what you expect a tug to do. There are many types of tugs, and as a branch of naval architecture the designing of tow-boats would be a specialty for any man, no matter how clever. If you go to Europe, if you go to Germany, if you go to Holland, or if you go to Canada, and here in the United States, you will find the tugs are utterly different, and that they are used in entirely different ways, and if you attempt to take a British tug and use it in America, or if you attempt to take a German tug and use it in America, or take a Canadian tug and attempt to use it somewhere else, and the same thing applies to an American tug, you will have lots of fun on your hands. I have tried it and know.

I set out last winter to make an experiment with an internal-combustion engine and a tug-boat. I built a tug 55 feet long and rather hurriedly ordered the tug before I had the engine, but I thought the internal-combustion engine people were up to date, and that I could probably buy the engine which I desired without any difficulty. I found that the Diesel engine that I wanted to employ, 110 horse-power, could not be built under 300 revolutions per minute, and as the tug was a business proposition to be used in towing barges about five times its own length, I did not take long to discover that 300 or 250 revolutions per minute were utterly out of the question. I went to the engine builder and said, "Give me a reducing gear. I want my engine revolutions reduced to 110 per minute." They finally fell down, because they could not get what was suitable, or did not want to be bothered with it. Finally I had to put in a steam engine, and the vessel is in Canada doing good work, with 120 revolutions per minute.

I do not hesitate to say, so far as my experience in tugs has gone, and I have had about six built in Canada in the last few years, if you want to get assured success—I do not mean in deep sea running—if you want general efficiency as a tug, not as a speed vessel, you want to keep the revolutions somewhere around 120. If you get above that, you will get into trouble.

One of the troubles that any designer has to face in studying a paper like Professor Peabody's is simply this: That, however he may agree with Professor Peabody's findings—and I agree with quite a few of them—you cannot always convert them into practice, because you have got to take a certain size of hull and a certain size of engine, because the engine builder can offer a standard type at a moderate price. Then you have to take a certain kind of propeller, because the man on board is familiar with it and wants one with which he is familiar. You are not free to have the boiler, engine, and propeller adapted to the ideas you have on the subject. Most people want the plans for a boat gotten out in a fortnight and they want the boat built in six weeks. They say, "We want the boat, we want it right now, and we do not want a lot of experiments with engines, propellers, etc."

I was going to say the reason I think in this country why such a peculiar propeller is used in tugs—and they are very peculiar; they are very interesting—if you study the propellers which are used for tow-boat purposes you will find there are as many freaks as there are good ones, but there is a reason for most of the

peculiar features. A point that Mr. Peabody did not touch on as much as he should have done, is that these peculiarities are largely caused by the necessity for maneuvering, backing and filling, and accelerating and retarding the movements of the tug in getting up to the tow and getting away from it before you ram your stern with it, and these things are of the utmost importance, especially in a tow-boat used in deep sea service. If you consider a harbor tug, it must be able to connect quickly with its tow, handle it smartly into its pier, must have the capacity for turning quickly; and frequently when the master of the tug finds he is going to hit the tow a lick, or the tow is going to hit him, he must be able to get away from it instantaneously, and that necessitates a certain type of propeller, and the efficiency of the tug, as a whole, is largely dependent on its ability to maneuver rapidly, especially in narrow waters. I think the peculiar propeller we find on the American tug is also due to the fact that, until quite recently, the majority of tugs were made of wood, and were fitted with ponderous stern frames and enormous rudders. Every one who has experimented with tugs knows of the tremendous influence the balanced rudders, made of broad wood, have on the propeller and the efficiency of the propeller, especially when towing.

Professor Wm. Hovgaard, *Member*:—The experiments described in this paper will undoubtedly be of great value to the designers of tow-boats, but I wish to draw attention to the fact that they will be of equally great value to the designers of ice-breakers.

As far as the propeller design is concerned, the two problems are about identical. In both cases it is required that the propeller shall develop maximum power under circumstances where a great resistance reduces the speed to a very low figure.

I have had some practical experience in the design of ice-breakers and of propellers for ice-breakers, and it is a satisfaction for me to see that these experiments corroborate the opinion which I have always held and advocated—that the propellers of ice-breakers should preferably have a low pitch-ratio. I met considerable opposition to this view of mine on the ground that the high pitch propeller shows up better on the speed trials in free water. It seemed obvious to me that a propeller, which worked under the most favorable slip at full power and high speed in free water, cannot possibly work to best advantage at nearly the same power when the speed is very much reduced, because the slip will then become excessive. With a low pitch-ratio, a high number of revolutions may be maintained with good efficiency even at very low speeds, and thus the engine is enabled to develop maximum power whereby a high thrust is obtained.

I may mention that in the ice-breaker Sleipner, built by Burmeister & Wain for the port of Copenhagen in 1895, we adopted a pitch-ratio of $\frac{15}{14} = 1.07$. She was of 2,400 indicated horse-power.

In the ice-breaker Nadeshny, built by the same firm for the Russian government for the port of Vladivostok, we adopted a pitch-ratio of $\frac{16.5}{14} = 1.18$. There was one four-bladed propeller, of a projected area ratio of .42, somewhat smaller

than the smallest ratio used in the experiments described by Professor Peabody. The power was 3,600 indicated horse-power. The Nadeshny was tried in the autumn of 1897, in the Finnish Gulf, where she maintained a steady speed of 3 to 4 knots through floe ice of a uniform thickness of 29 inches. She was subjected to several other successful tests which showed her excellent qualities as an ice-breaker, and bore out the advantages of a low-pitch propeller of moderate blade area.

Mr. Clinton H. Crane, *Member:*—I think that all of us in this Society, if we believe in this Society's worth, must appreciate a scientific investigation of any problem. I think all of us who have to do with the designing of tug-boats, the building of tug-boats, and the handling of tug-boats, realize that there is less scientific information about a tug-boat than about any other type of boat that is built in this country.

Some years ago we were called on to design a tug-boat for the Brooklyn Eastern Terminal. They had never used anything at all but wooden tug-boats. There was not a man in the place who would have anything to do with a steel tug-boat, because a wooden tug-boat "towed better." When asked, "Why does a wooden tug-boat tow better?" the reply was—"I don't know, but I have been on the Sempt, and know that she is better than any tow-boat in the harbor." I made a great many trips on the wooden tow-boats and looked into the steel tow-boats, and we finally built a steel tow-boat. When that tow-boat was finished, she was not doing work equal to any of the wooden boats; none of the men in the yard thought she was doing half as well—that was their opinion. We said, "All right; let us run a comparative test and let us see what the boats will do." We very carefully measured the water and weighed the coal, and timed the boats handling car floats in and out of the dock, and the time taken to convey the float from dock to dock, and we ran that thing for a period of over two months, and then we found that the steel tow-boat was doing 10 per cent more work than any of the other boats; but, all the same, she was no good, and even after the test was finished, the old shell backs were not convinced. My experience with tow-boat propellers is that the general idea is unless you put on a square tip, high pitch-ratio propeller, it is no good. I have personally been convinced for a long time that a low pitch propeller would tow better. It is absurd to use a slip of 60 or 70 per cent when you do not have to, and yet the times when we have put on low pitch-ratio propellers—and we tried them several times—they have never been a success. It is perfectly fair to say, as a matter of fact, that a low pitch-ratio will not handle the boat as well as a high pitch-ratio. It will not get the power to her as well, nor stop the boat as well, nor turn her as well—just why that is I have not been able to determine to my own satisfaction, and I rather hoped that Mr. Peabody, in his experiments, had made some handling experiments which would help us in that analysis.

I believe that the meal which Professor Peabody has prepared for us is worthy of a very careful digestion. It is a very full meal, and I think there are very few of us who can say how much we can use, and how much we cannot use, until we

study the matter further, but I believe we all can go ahead with more confidence on a new design by studying all the experiments which Professor Peabody has made.

Mr. W. T. Donnelly, *Member:*—As to the relation of handling tow-boats with coarse pitch and relatively small number of revolutions, it should be kept in mind that when working slow or starting up in handling a vessel, a steam tow-boat has stored up a large surplus of power. This perhaps is not realized by the captain or engineer, but it is an undoubted fact, and under those conditions the coarse pitch wheel in connection with the stored-up energy of the steam boiler can carry a very large overload.

It is probably a fact that efficiency under such circumstances would be much below that shown by Professor Peabody's experiments, but efficiency under the conditions referred to, that is, the nosing about of vessels by a tug, is something that the captain and engineer of the tug would have little or no sympathy with and relatively would be of little or no importance.

As was said by the last speaker, there is no question but that a coarse pitch screw handles the boat quicker and better. We can readily understand that because it will absorb much more power, and there is nothing in the experiments conducted by Professor Peabody which would in any way contradict these facts, and in all probability both the statements of the practical man and the scientific man are true when properly understood.

There is certainly no question but that, as engineers, we must weigh and measure to determine the energy we are using and results can be predicted in no other way.

It is equally important to consider carefully the experience of the practical as well as that of the scientific man, and it is certain that they cannot reach the best results without thoroughly understanding each other. Most of their differences arise from a misunderstanding of the terms and expressions used, each being unfamiliar with those of the other.

The President:—Are there any further remarks on this paper? If not, I will ask Professor Peabody to close the discussion.

Professor Peabody:—I was, in anticipation, prepared for objections to any or all of my conclusions in the paper just presented, but I cannot quietly submit to the imputation that because the work is done in a scientific manner it therefore cannot be practical and is to be set aside by anyone who says "This disagrees with my experience." I claim that in this paper there is a wider variety of experience than can be found even in long years of experience in a narrow line of practice when only one type of propulsion is used and cannot be varied. The fact that a slow engine was found desirable in a given case is no proof that with proper design a high-speed engine cannot be used. At the same time I appreciate that the designer is limited by his conditions, including the prejudices of those who are to handle the boats, and this is recognized in the paper.

I cannot believe that the wide stern post of a wooden tow-boat is a determining reason for the typical wide-tipped tow-boat propeller, for our medium width, well-rounded blades did well on the Froude, which has a wide stern post.

We did not make experiments on stopping and starting and handling in general, as we had not time last summer. Several speakers claim that a coarse pitch wheel will handle a boat better than a fine pitch wheel, doubtless with good reason; if we have opportunity we will try this also and ask that weight shall be given to our experience.

I venture to suggest that stored power turned suddenly on a slow engine may have less alarming effects than would be found with a quick running engine. And further, quick-running engines must in general be built and run with more care; and yet automobile engines and power-boat engines manage to take care of themselves in the hands of unskilled people.

While we claim we have obtained important results we have no desire to recommend specific conditions, but, rather, we wish to enable the practical designer to choose his conditions with wider information. In particular our range of pitch-ratios was designedly taken wider than need be used in good practice, and I have no desire to urge low ratios and quick engines for a service where so much depends on employing inexperienced men.

It is gratifying to learn that the experience of my colleague, Captain Hovgaard, corroborates our conclusions.

The statements concerning the service of tow-boats given by Mr. Crane call to mind anecdotes by tow-boat men. When solicited by a tow-boat captain they change the propeller and he always reports that the wheel he favors does very much better. On one occasion a certain wheel was taken off to be changed, and by mistake was put back on again; nevertheless the captain reported the boat to be doing very much better. I believe that any tow-boat captain who favored a wooden boat could make it out ten per cent better than a steel boat, even though Mr. Crane proved the advantage to lie the other way.

One more point only I wish to emphasize: our indirect drive allowed me to change from a large pitch to a small pitch and yet to drive with full power for each wheel; this you cannot do with a steam-engine or an internal-combustion engine which must run at its own proper speed to develop its power. If you choose too large a pitch-ratio you slow the engine below its power, but if you take too small a ratio the engine runs away before it can develop its power.

The President:—The thanks of the Society are due to Professor Peabody for his very able and interesting paper.

We will now have the paper entitled, "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. N., a Member of Council.

Mr. Robinson presented the paper.

THE DESIGN AND NEW CONSTRUCTION DIVISION OF THE BUREAU OF CONSTRUCTION AND REPAIR OF THE NAVY DEPARTMENT.

By Naval Constructor R. H. Robinson, U. S. Navy, Member of Council.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1911.]

This article proposes to deal only with the methods of handling an organization engaged in design and in passing on matters of new construction, leaving the work produced to speak for itself.

The work of this Division of the Bureau of Construction and Repair is of course but one component part of the whole work of the Bureau, which is charged with many and varied other functions. Although its work is to a great extent self-contained and to some extent independent of the other divisions of the Bureau, it would be impossible to carry it on without access to the records and data available only in the Bureau's main records. Conversely the balance of the Bureau could not function without this Division.

The Division has no independent correspondence files, but depends on the main files of the Bureau.

This Division produces in general:—

(*a*) Estimates for new construction.

(*b*) Preliminary designs for ships, including plans and calculations.

(*c*) Contract designs for ships, including plans, calculations and specifications.

(*d*) Action on contractors' plans and on specifications for auxiliaries submitted by builders.

(*e*) Standard plans and miscellaneous design work.

Incidental to each of these are many duties, some of which are handling the reports of boards on changes on ships, the compilation and tabulation of data for use in one of the main duties mentioned above, preparation of allowance lists, design and record of issue of small boats, preparation of annual report and ships' data books, etc. A definite section also handles the question of reports of the trial board, takes action on the more important alterations to ships in service, etc.

The endeavor is to produce the greatest amount of work possible with a minimum effort and in a minimum of time.

With the object of saving time, a complete study has been made and a number of what the writer considers the most important features of modern shop methods have been adopted, particularly in routing, assigning and

planning work, making provision for consultation with responsible officers without delay, etc.

In technical work of this kind, involving responsibility for many millions of dollars' worth of work and requiring careful engineering investigation in the original design, and careful examination in the criticism of contractors' plans as submitted, the writer does not now believe that "time setting" for the actual technical work is desirable. Time studies of various non-technical elements have shown great opportunities for improvements, and we are striving for more improvement. Records of the time required in the various technical parts of designs of different classes of ships are kept, careful consideration is given to the relative value of the employees and records of actual progress of jobs are kept for comparison with the estimated progress. These are of great value in checking the estimates of time for succeeding designs and permit accurate estimates of dates when jobs can be completed, but nothing like task setting for individual workmen in the shop has yet been attempted for the technical employees, nor does the writer now think that it will be.

The Division is divided into five parts:—

1. The "office."
2. The electric branch.
3. The criticism branch.
4. The design and scientific branch.
5. The blue print room.

Number 4 is further divided into two parts, the design room and the scientific and computing room, but both work directly together and directly adjoin. The design room also includes the specification desk. A diagrammatic arrangement of the Division would be as shown in Plate 20.

It might be interjected here that the physical arrangement, while good, is not ideal, since the various branches are separated by some distance and the space is somewhat congested. This is due to conditions which cannot be overcome at present.

A diagram of the physical arrangement is indicated in Plate 21.

The Office.—In the office is desk space for four officers, the writer and three assistants. The arrangement of the office is shown by Plate 22.

Frequently one of the officers must be absent on other duties, but one of the officers, the senior assistant present, is always at the desk to handle papers, answer the telephone and keep in touch with all ends.

As he handles and reads about seventy incoming letters and sixty-five outgoing letters each day, to say nothing of his other duties, his day is busy.

Another assistant spends practically his entire day in the criticism

branch, going from desk to desk, giving instructions, answering questions, etc. The third assistant is at present developing a special line of work, which also keeps him in the criticism branch. Eventually it is hoped that it will work out that there will be an officer continually in each of the design and criticism branches.

The writer, as head of the Division, spends about one-quarter of his time at his desk, and the balance with the chief constructor, in the drawing offices, mostly in the design and scientific branch, or in expediting inter-bureau work about the Department. It is the writer's duty as the head of the Division to keep the chief constructor informed of the work of the Division and to keep advised of his wishes.

The Electric Branch.—The electric branch, which immediately adjoins the office, is directly controlled by the officer at the desk. It includes the Bureau's electrical aide and the assistant electrical aide, one of whom is always on hand and both generally, although sufficient outside inspection trips are ordered to take care of the work and to keep in touch with outside progress. The arrangement of this branch is shown in Plate 23.

Its work consists of preparation of and action on electrical specifications and plans, passing on electrical test reports, design of electrical auxiliaries, keeping track of electrical subordinates outside the Bureau and in general all electrical questions before the Bureau. Special investigations of new electrical applications for the Bureau's work on board ship are made in or directed from this branch.

The Criticism Branch.—This branch examines and criticises:—(*a*) plans produced in design branch before issue; (*b*) plans and specifications submitted by builders in developing the details.

It is under the immediate direction of the chief draughtsman who, in addition to his responsibility for discipline and general oversight over the whole force, acts as foreman of this room. The employees are rated as draughtsmen, though in an engineering firm such as the General Electric Company similar employees would doubtless be called assistants of the engineering staff. Besides the chief draughtsman and his assistants, there are fifteen draughtsmen with stenographers and plan clerks. This branch is organized on the functional system, each employee or group of employees handling a specialty or kindred specialties. The specialties covered are considerable in number and are divided generally as follows, with one or more employees to each subdivision:—

Changes; allowance lists and small boats; plans, their filing, correction and distribution to navy yards; joiner work and general arrangement; repairs and alterations of ships in the fleet, trial reports, etc.; structural

work; auxiliary machinery and mechanical details; ventilation, drainage, and piping systems; turrets, gun emplacements and armor; submarine boats; miscellaneous.

A detail of the distribution of duties is indicated in the following form. No names of employees are here inserted, though in the form in use, of course, the names are filled in.

CRITICISM BRANCH.

Subject.	Responsible.	Assistant.	Relief.
Access and compartment			
All subjects			
Allowances			
Alterations and repairs			
Ammunition hoists (other than those in turrets)			
Ammunition stowage and handling			
Anchor handling			
Armor			
Arrangements, general			
Ash expellers and ejectors			
Berthing and messing			
Bitts			
Blocks, trolley			
Boat cranes			
Boats; building and issue			
Boats; design			
Booklet plans			
Booklets of general information			
Capstans			
Changes under contracts			
Chocks			
Coaling at sea			
Collars, water-cooled			
Collier questions			
Commissary arrangements			
Compartment and access			
Complements			
Compass			
Contract time, extensions of and delays			
Contracts; legal matters			
Contracts; changes under			
Contractors, ship; responsibility for defective work			
Contractors, ship; final settlements with			

CRITICISM BRANCH.

Subject.	Responsible.	Assistant.	Relief.
Contractors' working plans			
Correction of plans required			
Correspondence, current incoming			
Cranes, boat			
Cranes, torpedo			
Deck covering			
Defective work; responsibility of ship contractors for			
Delays and extensions of contract time			
Distinguishing marks			
Dishwashers, vegetable cutters, and meat slicers			
Door (watertight) operating gear			
Draught gauges, internal			
Drainage			
Dynamo arrangements, structural			
Elevators			
Engrossing, Secretary's			
Extension of contract time, and delays			
File; confidential information			
Final and preliminary trials			
Finished plans			
Final settlements with ship contractors			
Fire control structures			
Fire mains; fresh and salt water systems			
Fire control systems			
Forms for proposals for new vessels			
Foundations, gun			
Foundations, miscellaneous			
Fresh and salt water systems; fire mains			
Fuel oil			
Furniture, metal			
Garbage incinerators			
Gas ejecting			
Gauges, internal draft			
Gear, door (watertight) operating			
Gun foundations			
Gunports			
Handling and stowage, ammunition			
Hardware			
Hawse pipes			
Hawser reels			
Heating and steam piping			

CRITICISM BRANCH.

Subject.	Responsible.	Assistant.	Relief.
Hoists, ammunition (other than those in turrets)			
Hospital arrangements			
Incinerators, garbage			
Information, general, of booklets			
Insulation, magazine			
Internal draft gauges			
Joiner arrangements			
Laundries			
Legal matters; contracts			
Legal points, as regards new specifications			
Lights, signal			
Magazine cooling (refrigeration)			
Magazine insulation			
Magazine sprinkling			
Meat slicers, dishwashers and vegetable cutters			
Messing and berthing			
Metal furniture			
Militia, naval			
Naval militia			
New specifications, as regards legal points			
Nicholson logs			
Oil fuel			
Outboard fittings and rigging			
Painting			
Periscopes			
Photographs			
Plan files			
Plans, booklet			
Plans, contractors' working			
Plans, finished			
Plans, finished, record			
Plans, miscellaneous, issue			
Plans required and correction of			
Plans; standard and general type, revision			
Plans; standard and general type, record			
Plans, titling			
Plumbing			
Preliminary and final trials			
Proposals for new vessels; forms for			
Range finders			
Record, finished plans			

CRITICISM BRANCH.

Subject.	Responsible.	Assistant.	Relief.
Record, standard and general type plans			
Reels, hawser			
Refrigeration (magazine cooling)			
Repairs and alterations			
Requisitions			
Responsibility of ship contractors for defective work			
Rigging and outboard fittings			
Safes			
Salt and fresh water systems; fire mains			
Scuppers			
Scuttle butts			
Sea chests			
Secretary's engrossing			
Ship contractors; responsibility for defective work			
Signal lights			
Settlements, final, with ship contractors			
Standard and general type plans, record			
Standard and general type plans, revision			
Steam piping and heating			
Steering engines			
Steering gear			
Storerooms and staterooms, assignment of			
Stowage, ammunition, and handling			
Structural; dynamo room arrangements			
Submarines			
Submerged torpedo tubes			
Surveys			
Telephones			
Titling plans			
Torpedo cranes			
Torpedo boats (ventilation)			
Torpedo boats, weights for			
Torpedo tubes, submerged			
Towing gear			
Trials, preliminary and final			
Trial board data			
Trolley blocks			
Tubes, submerged torpedo			
Turrets			
Turret turning gear			
Type plans, standard and general, record			

CRITICISM BRANCH.

Subject.	Responsible.	Assistant.	Relief.
Type plans, standard and general, revision			
Vegetable cutters, dishwashers and meat slicers			
Ventilation (torpedo boats)			
Ventilation			
Voice tubes			
Water-cooled collars			
Water, fresh and salt systems; fire mains			
Weights for torpedo boats			
Winches			
Windlasses			
Working plans, contractors'			
Utility			

In this room the chief draughtsman and his assistant, the draughtsman in charge of changes, the draughtsman in charge of allowance lists and his assistant, and the stenographers, have desks. The others each have a table of standard form. Each table has a uniform arrangement and a uniform outfit of instruments, reference books, and supplies, with special additions to the standard outfit for employees doing special work. The arrangement of this table is shown in Plate 24.

In this room in a gallery are the main current plan files, kept in metal cases and under the charge of a special plan clerk. Owing to lack of space, the considerable size of individual plans, and partly to the fact that it was so started, these plans are filed, rolled, in pigeon-holes. Space does not permit stowage of all plans, so only the plans of ships building and one or two classes back (those most constantly referred to) are stowed here. The balance—a very large number—are kept in fireproof vaults at the Washington Navy Yard, from where a plan can be obtained twice daily by regular trips established or in about half an hour in any emergency by the use of the telephone.

Under the gallery and in recesses along the wall, so as to give a smooth wall surface, is a card index of all plans, whether stowed in the gallery or in the Navy Yard vault. Here also is kept a card index of all photographic negatives, of which a considerable number are taken for ships building. The negatives themselves are kept at the Navy Yard.

In this room are provided:—

(*a*) Height poles marked in feet and inches for use in measuring and judging heights.

(*b*) Standard boards with samples of various sizes of pipes, ropes, bolts, nuts, chains, etc.

(*c*) A sample case with samples of various standard fittings and accepted materials.

(*d*) Color boards with samples of accepted navy colors.

At every alternate table for the use of two tables is a rack of photographed booklets of record contract plans as issued.

The walls of the room are painted yellow with white trimmings. The ceiling of the room and the under side of the gallery are white.

The room is lighted by eighteen 60-watt tungsten lamps with holophane reflectors. The lights are about 9 feet above the floor and are controlled in pairs. Three 40-watt tungsten lamps with ordinary shades are provided over certain desks. In the gallery are located eight 40-watt tungsten lamps with holophane reflectors.

Electric fans are also provided:—(*a*) for agitating the air in summer, (*b*) for exhausting air through openings into the corridor in winter, fresh air coming in behind glass screens in the windows.

Heavy solid color red linoleum is used on all walking and standing spaces on the floor and all furniture is made so that cleaning under and around it is easy.

Plate 25 shows the arrangement of this room.

The Scientific and Design Branch.—This branch produces the plans, specifications, and calculations for new ships of the Navy.

It is under the direction of a leading draughtsman with another leading draughtsman directly in charge of the design plan room itself. The design plan room contains ten draughtsmen, eight of whom make and trace the plans and two prepare the specifications, filling what is called the specifications desk. The leading draughtsman and the two draughtsmen working on specifications have desks; each of the others has a table of standard form. This table is exactly similar to one-half of that in the criticism branch except that the top is 8 feet long, of heavy white pine with a trued steel edge, and there are no racks on top of the table. In connection with this steel-edged table we use a special form of steel T-square which holds its shape better and causes less interference with the workman than the usual wooden square.

There are no considerable plan files in this room and the copy of the finished product for current use is carried in the main plan files, so that only sketches are filed here. Provision is made for such filing.

For use in connection with the work of this room—although located in another room on account of lack of space—is a marbleized glass table used for laying down and fairing lines. This table is 3 feet by 14 feet.

We have also an outfit of modeler's clay which we use in working up and checking unusual forms.

This room is painted in the same way as the criticism branch and the floor covering is the same.

The lighting of this room presented some special difficulties owing to the fact that, unlike the other rooms, all the work herein is draughting.

It has been solved satisfactorily by using eleven 60-watt tungsten lamps 7 feet up and so located as to throw the light from the front of the board instead of over the shoulder, thus avoiding shadows.

Plate 26 shows the arrangement of this room.

Scientific and Computing Room.—The scientific and computing room contains thirteen draughtsmen at the boards engaged on all kinds of scientific investigations, calculations and computations as to ships. The leading draughtsman and his assistant have desks, and each of the others has a table fitted out with computing and calculating instruments, etc. This table is a duplicate of one-half of that in the criticism branch but without racks on top and with the computing instrument rack added. There is provision in this room for filing, in metal cases, the plans, calculations and records pertaining to the strictly scientific end of the work, such as stability calculations, estimates for projects, displacement calculations, strength calculations, weights estimated and returned, etc.

This room is lighted by twelve 100-watt tungsten lamps about 10 feet above the floor. The painting is similar to the criticism branch. The floor covering is the same.

Our outfit of mechanical calculating instruments comprises:—

Nine comptometers and 1 comptograph.

Six arithmometers of various types.

Two Fuller slide rules.

Two integrators.

Five planimeters of various types.

Sexton's omnimeters are supplied to most of the draughtsmen in the Bureau.

Plate 27 shows the arrangement of this room.

The Blue Print Room.—This is in two parts—one in the Bureau and the other at the Navy Yard. Originally all blue prints were made in the Bureau but the number increased so that our facilities for making them were inadequate and our room for expansion was insufficient. Accordingly the old blue

print room was retained, but makes only from thirty to forty prints per day. This work is done by an employee who has other duties in addition. Other blue prints are made in the blue print room at the Navy Yard. The equipment of the old room consists of a continuous motion machine with a mercury vapor tube light, and an older cylinder arc light machine.

The blue print room at the Navy Yard includes two continuous motion electric machines with multiple arc lights, one machine being fitted with a washer and drier.

We have also in this room a photostat machine and a lithoprint outfit for reproducing tracings, both of which are of immense value to an organization such as ours.

Blue prints made for issue are mailed direct from the blue print room to address given on print order. Each order is numbered consecutively and the number of each order filled is reported daily and checked off so as to prevent confusion.

Blue prints made for the Bureau are sent direct to the branch ordering them.

The form for ordering blue prints is as shown on page 30.

Planning Boards.—Planning boards are fitted in the office, in the design branch and in the scientific and computing branch. The other rooms have no boards as the individual jobs done in these rooms are short and do not involve distribution of labor among several employees.

The boards in the rooms contain hooks under the names of the several employees on which the plan cards are hung, and hooks, (*a*) for jobs to be planned, and (*b*) for jobs completed.

The plan board in the office contains hooks for the various assistants and for the branches, but does not go so far as the individual in the room.

Method of Work.—The products of the Division enumerated above nearly always result from the receipt of a letter; for example, if the Secretary of the Navy wants a ship designed he writes a letter; if a contractor wants action on a plan, or if a superintending constructor wants instructions, we receive a letter.

It therefore is of primary importance to get the contents of this letter, which is the commercial manufacturing company's purchasers' order, together with the instructions on it, to what the manufacturing company would call the shop, in the form of a shop order, in the minimum time.

This letter is opened in the office of the chief clerk of the Bureau, entered in the main correspondence files and routed flat by means of a route tag (see page 31). The letter is dropped into an outgoing basket in the file room, picked up by a messenger on a regular route, and deposited in a receiving

ORDER NO.	VESSEL.
MAIL TO—	

TO ACCOMPANY BUREAU'S..... No.

NOTE.—DRAFTSMEN TO DENOTE BY MARK X AND PROPER SYMBOLS AND OTHER INFORMATION THE ACTION TO BE TAKEN.
PLAN CLERK TO INSERT ORDER NO. AND DESIGNATE PLACE TO BE FILLED.

ACTION-TAKEN SYMBOLS.

AD=APPROVED AS DEVELOPMENT.
ADM=APPD. AS DEVELOPMENT SUBJ. TO MOD'S.
AC=APPROVED AS CHANGE.
DIS=DISAPPROVED.
REV=REVISION.

ORDER TO { BUREAU EMPLOYEE. / NAVY YARD, C. AND R. }

PLAN CLERK.		BLUE PRINTER.	
TO FORWARD ATTACHED ENCLOSURE.		TO MAKE AND FORWARD PRINTS AND RETURN ORIGINALS TO BUREAU.	
TO OBTAIN AND FORWARD ENCLOSURE.		TO MAKE PRINTS, FORWARD ORIGINALS AND SEND PRINTS TO BUREAU,	
TO MARK PLANS AND FILE CARDS AS TO ACTION TAKEN.		TO MAKE PRINTS AND SEND ORIGINALS AND PRINTS TO BUREAU.	

NUMBER REQUIRED.	KIND.	ENCLOSURE. (If possible, give file number and title.)	ACTION TAKEN.

APPROVAL OF C. O. FOR NAVY YARD ORDERS. } SIGNATURE OF DRAFTSMAN. DATE. N.C.R.81

N. C. R. 89 SERIAL No.....

Date.....

Subject.....

File No.....

IN OUT

Chf.	Const'r
Chf.	Clerk
Cor.	Desk
N. C.	Taylor
N. C.	Robinson
N. C.	DuBose
N. C.	Spilman
N. C.	McBride
N. C.	Radford
N. C.	Ackerson
A. C.	Land
A. C.	Howard
A. C.	Gawne
Chf.	Draftsman
Pln.	Clerk
Fin.	Clerk
File	Clerk
Req.	Clerk
Cor.	Room
Mr.	Anderson
Mr.	Bennets
Mr.	Borland
Mr.	Brill
Mr.	Capdevielle
Mr.	Dean
Mr.	Godbold
Mr.	Jones, W. T.
Mr.	Quinn
Mr.	Wallace
Mr.	Wheater
Mr.	Whitaker
Mr.	Wilson
Mr.	Winterburn
Mr.	Wyche
Mr.	Young

Obtain report, recommendation (and estimate).....
Show me P. C.; plans .....
See remarks inside .....
To.....for comment.
Show N. C.....in D. R.
Forward (req. return).....
Return .....
Contents noted .....
Authorize or approve .....

Has subject been referred to bureaus concerned?.....
Who passed on the question? .....
Is any change involved? .....
Has Department approved? .....
Sister ships considered? .....
Does it affect future designs or specifications?.....
Standard plan require revision? .....
Red card?.....
Other draughtsmen interested?.....
Have necessary prints been ordered?.....
Plan clerk notified of action on plan? .....
General subject file?.....
(17777)? .....
(17735)?.....; Pink carbon?.....

FILE	*DATE*

basket at its destination as indicated by the name underlined. This slip remains attached to the letter on its return journey and to the file copy after it is in the files. If the letter covers work in this division it comes to the writer's office; if in another officer's it goes to him.

Here were two points where the time study gave good results, in (*a*) reducing the time to open, enter, and start a letter; (*b*) the time to get it on its way. Both are done in a regular, orderly manner, the first by the file-room force, the second by a messenger on a definite route, making one round trip of his whole route in ten minutes. This messenger starts from the chief clerk's office, goes to each room and to each desk that performs work, in a regular order, deposits his burden in a definite place and picks up material in an outgoing receptacle. A copy of his instructions is here shown:—

MESSENGER SERVICE.—The following instructions will hereafter be followed by messengers collecting and distributing mail to rooms Nos. 189, 187, 185, 183, 181, 179, 177, 174, 175, 176, 178, 182. Beginning at 9 a. m. each day one messenger is to make trips along the following route, beginning in room 178, then to rooms 182, 189, 187, 185, 183, 181, 179, 177, 174, 175, 176, returning at the end of the trip to room 178. At each half hour he is also to take out-going mail to the department post office and bring back mail for the bureau and deliver the same at the correspondence desk. These trips will be made consecutively and each time a trip is completed the time of completion is to be entered on a slip kept in room 178. Messengers are to acquaint themselves with all baskets in each room for incoming and outgoing mail, and be careful to move all mail in the route indicated on the reference slips. The messenger assigned to this duty is to do this duty alone during the period so assigned, and is not to be sent on messages or other duties which will take him off his route. Should anyone request him to make such trips not on his route, he is to inform the person of the instructions contained in this memorandum and request the person to send for another messenger. Should anyone insist on the messenger going on any message which interferes with his regular route, he is to inform the officer in charge of the correspondence desk, who will, if necessary, bring the matter to the attention of the chief constructor for instructions. A messenger is also to be assigned to make trips on the route described above during the time from 12.45 to 4.30 p. m. So far as possible messengers are to be alternate; that is, the messenger who makes the morning trips will not be required to make the afternoon trips, but the afternoon duty is to be taken up by another messenger.

The slip records of time at which each trip is completed are to be sent at the end of each day to the time clerk, who will retain the same until the efficiency cards are being made out, at which time they will be brought to the attention of the chief clerk for consideration when assigning marks.

On arrival at "the office" of this division, a letter which probably comes with a number of others always finds some one ready to read it and to give instructions. In general, letters received may be classified as:—

(*a*) Perfunctory, on which the course of action to be taken is plain and instructions from the office can be reduced to "yes," "no," "do," "O.K.," "usual," "file," "forward," etc.

(*b*) Secondary importance, on which instructions cannot be quite so brief, but can be reduced to such as—"tabulate and show me," "show Mr. A. in D.O.," "O.K. if specifications cover as stated," etc.

(*c*) Primary importance.

(*d*) Special.

Letters of classes (*a*) and (*b*) are routed by the officer at the desk direct

to the employee handling the subject by drawing a line under his name or adding his name if not printed on the slip, with the instructions indicated on the route slip, and dropped in the outgoing basket to be picked up on the next round by the messenger. Such a letter should therefore be at the destination where the work is done on it in one-half hour from the time it is started on its route after entering in the files, or one hour from time of arrival in the Bureau.

Plans received with letters are routed direct from the file room to the employee and generally reach him before the letter. To make this possible the file room has a copy of the key to distribution of duties of employees and few errors of routing occur.

Letters of classes (*c*) and (*d*) are put on the writer's desk to receive instructions from him or from the chief constructor himself.

As the writer is generally advised of the chief constructor's wishes, class (*c*) can ordinarily have instructions given directly. Class (*d*), the fewest in number, must usually be taken up with the chief constructor for special instructions. After receiving the instructions both follow the same routes as the others.

Jobs for the criticism branch go direct to the employee handling the special subject, and his desk or table is visited periodically each day by the chief draughtsman (acting as direct head of this branch) and by the officer on duty in this room. Such visits to each desk or table number three to six by each of these responsible people each day, and also, though less frequently, visits are made by the writer as head of division, when it is desired to look into some special subject.

Jobs for the design and scientific branches, which generally require more than one man to work on them, go to the leading draughtsman in charge of the room and not to the individual employee, and are planned and assigned as will be explained below.

Supplying Materials.—It now becomes of importance to get to the employee the necessary material with which to do his work. This usually consists of plans, specifications and previous correspondence, sometimes of reference books other than those in his standard outfit or previous calculations. Immediately on the receipt of a letter—which generally comes with the others of that day's jobs—the employee looks it over and sees what he needs and makes out requests for what he requires of the following:—(*a*) for letters from the files; (*b*) books from the library, or (*c*) information from another branch, as shown on page 34. This form he drops into his outgoing basket to be taken up by the messenger. For plans he makes request on form

NAVY DEPARTMENT,

BUREAU OF CONSTRUCTION AND REPAIR,

Washington,....., 19

NAME OF SHIP.

.....

INFORMATION DESIRED.

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.....

√ = GIVEN TO SIGNER.
× = REQUESTED FROM N. Y.
⊙ = RECEIVED FROM N. Y. AND GIVEN TO SIGNER.

SHIP.					

DATE SIGNATURE

N. C. R.—5.

as shown on page 34, which he drops into a box suspended by a string from the plan gallery, which is periodically examined by the plan clerk and the requested plans taken out, charged and dropped on the desk requesting them direct from the gallery. If the plans are at the Navy Yard the plan clerk telephones for them.

The draughtsman can then go about his other work, and by the time he is ready to take up the job the material necessary will be ready, at his desk, being brought by the regular messenger system.

Action.—Letters of action are prepared by the employee doing the work. His work during the preparation of material for the letter is frequently vised, and help, advice and more detailed instructions given by the chief draughtsman and the officer on duty in the particular room.

All subjects are vised by one or both of these responsible men.

All letters are written in conformity with standard forms of which we have issued printed samples.

Formerly, all such letters were written on scratch paper, dropped into the outgoing receptacle with a tag marked "Typewriting Division," and taken by the messenger on his regular route to the typewriting division where they were written and returned by the regular messenger system to the writer for final checking. More recently we have been detailing stenographers to make regular trips though the drawing rooms at stated times to receive the letters by dictation.

A trial has been made of the dictaphone but so far we have not been able to make a success of it.

In the criticism branch where no plan board is used, a running list of jobs received is kept by each employee entered on a form provided for the purpose, showing date of receipt. When the job is completed he enters the date of completion and draws a line through the whole entry.

This current record is kept in view on the top of each desk or table and is consulted by the visiting officer to insure that tasks are being treated in the order of their urgency and that nothing is overlooked. Jobs more than six days old require special explanation. A sample of this form is shown on page 18.

Tickler.—A great assistance in all parts of the work has come from establishing a "tickler box." Special colored cards are supplied to all employees on which they enter memoranda of things they wish to be reminded of. These are dropped in the basket and by their color are known to be for the tickler box, where they go by the regular messenger system.

Planning.—If the job is long and complicated it is marked "plan" on the route slip.

In the case of a job in the design and scientific branch, if it can be taken

N. C. R. 111.

DRAFTSMEN'S WEEKLY REPORT OF WORK. Date.....

LIST OF UNANSWERED AND UNCOMPLETED CORRESPONDENCE OR WORK IN MY HANDS.

SHIP.	BRIEF OF SUBJECT.	LETTER NO. AND DATE.	RECEIVED BY ME.	ACTED ON BY ME.	CHASER SENT.	REMARKS: Under this head say "Answered," "Referred to Bureau," etc.

up at once it is planned by the leading draughtsman and his assistant, generally in consultation with the writer, to whom the plan is always submitted for approval, and plan cards are made out. A set of cards assigned by individuals is put on the planning board in the room concerned, and a single card with a very brief digest of the job and the promised date of completion is put on a similar board in the office. If it cannot be undertaken at once it is put on the "Jobs to be done" hook on the board in the room concerned until it can be taken up for planning. A complicated job requiring several men to work on it is analyzed into its component parts, individual instruction cards are made out for each employee who is to work on it, and these cards are each hung on the hook belonging to the employee who is to take it up, in the order in which he is to take it up. A sample card is here shown:—

Job Ship

File No.

References

Instructions

Issued to Charge

Started Total Hours

Finished

Each employee's hook generally contains cards with instructions for (*a*) the job he is working on, and (*b*) the next two jobs he is to take up. Standard jobs which are repeated periodically, such as analyses of inclining experiments, checking measurements of coal bunkers, and many others, have standard instructions in printed or typewritten form, as follows:—

S. & C. Branch, Nov. 14, 1911.

INSTRUCTION NO. 1.

Procedure for Checking Inclining Experiments.

1. Go through entire experiment roughly.
   Has it the required conditions,
   displacement sheet,
   cross curve sheet,
   statical stability sheet?
2. In case of new ships compare light conditions with similar condition worked up from returned weights.
3. Latest inclining experiment of sister ship.
   Compare G. Ms., trims, displacements with.
   Compare with previous experiment for ship.
4. Go carefully through experiment data item by item.
   Sheet No. 1—Check general dimensions with Chief's report or booklet.
   In new ships check designed data.
   Note position of base line for draught marks.
   Sheet No. 2—Look into question of free water.
   Density of water.
   Is trim excessive?
   Sheet No. 3—Method of handling weights.
   Check through one complete operation and compare with others.
   Sheet No. 5—General location and amounts of weights,
   Water in boilers, coal and feed water,
   Are inclining weights included in weights to deduct?
   Sheet No. 6—Check carefully, item by item, through Condition II, using Bureau's displacement. Special attention should be paid to longitudinal C. B. Condition I. In case trim of Condition I is excessive special calculations should be made for longitudinal C. B.
   Sheets No. 7 and 11—If Condition II has been found to be correct, compare weights and locations of same with designed figures on file in Bureau; also see if variations in trim and G. M. appear logical. If Condition II be incorrect, check only weights and locations.
   Sheet No. 12.—See if results are rational.
   Sheet No. 13—Check with Bureau's displacement sheet one spot on every curve.
   Is reference line for longitudinal C. B. located relative to midship frame?
   Examine location of base line.
   Sheets 13 and 14—Compare with those on file at Bureau for this ship.
   Compare with those on file at Bureau for sister ship.

Conditions Required:

I—Experimental condition.

II—Light condition.

III and IV—Designed normal and full load. (This primarily for new ships for comparative purposes.)

V and VI—Same as III and IV, except actual instead of designed loads.

VII—A possible condition of loading tending to materially decrease the metacentric height from that in normal condition.

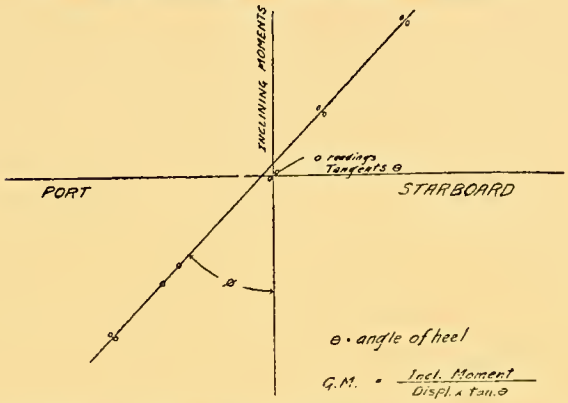
(This condition may be omitted for ships without upper bunkers).

Sheet giving effects on metacentric height for loads on various decks under varying conditions of load.

VIII—Damaged stability condition.

INCLINING EXPERIMENTS.

Method of Comparing and Checking Observations.



If inclining moments are platted as ordinates and tangents θ, derived from pendulum readings, are platted as abscissæ and a straight line drawn through the points (see sketch) then:

$$\frac{\text{Inclining moment}}{\tan\theta} = \text{scale factor} \times \tan\theta$$

and

$$\text{G. M.} = \frac{1}{\text{disp.}} \times \tan\theta \times \text{scale factor.}$$

Final inclining experiments have to be approved by the Bureau. A copy of the final inclining experiment has to be sent to the vessel by the Superintending Constructor.

If corrections are necessary write a letter using Form "A." When corrected by Superintending Constructor, approve using Form "B."

Date and sign the title page each time around and when ready to approve have Simpson mark "approved" with official stamp.

.....
In Charge.

Instruction No. 1. Form "A."
No. 22111—E. 17. (CM).

NAVY DEPARTMENT,
BUREAU OF CONSTRUCTION AND REPAIR,
WASHINGTON, D. C.

From Chief of Bureau,
To The Superintending Constructor, Fore River Shipbuilding Co., Quincy, Mass.

Subject: (E)—NORTH DAKOTA; Inclining Experiment Data.

1. References:
Sup. Con. Let. March 9, 1911, 23–2.

2. Referring to booklet of inclining experiment data for the NORTH DAKOTA, S. & C. B. No. 00234, forwarded with above letter, the Bureau notes the following:

Sheet 1.—Depth molded is not in accordance with that shown on mold loft lines. Freeboard should be given to the top of deck planking, not to the molded deck line.

Sheet 6.—Please add a condition similar to Condition II, but including alterations made at Navy Yard, Boston, Mass., in order that there may be a light condition directly comparable with the returned weights.

A note should be added on Sheet 6, calling attention to the new condition.

In the condition calling for actual weights of load, the coal, reserve feed water, and potable water should be in accordance with actual stowage capacities, and the supplies and accounts' stores should be worked up for the design period from the schedule furnished with Bureau's letter No. 409-A-175; 13181-A-195, of June 2, 1910. If the actual weights of the remaining stores are not available, the design weights may be used.

Sheet 12.—A note should be added on the curves of transverse metacenter and center of buoyancy, indicating the reference line through which the curves are read. The reference point for curve of center of gravity of water-line should be stated. The scale for curve of addition to displacement for one foot change of trim by stern should read "$\frac{1}{8}$-inch equals one ton."

3. Booklet of inclining experiment data, referred to, is returned under separate cover for revision in accordance with the foregoing.

Instruction No. 1. Form "B."
No. 22111—E. 18.

NAVY DEPARTMENT,
BUREAU OF CONSTRUCTION AND REPAIR,
WASHINGTON, D. C.

From Chief of Bureau,
To The Superintending Constructor, Fore River Shipbuilding Co., Quincy, Mass.

Subject: (E)—NORTH DAKOTA; Inclining Experiment Data.

1. References.
Sup. Con. Let. May 15, 1911, 23-2.

2. Inclining experiment data for the NORTH DAKOTA (S. & C. B. No. 00234), forwarded with letter referred to above, is approved.

3. Copy of this booklet should be furnished the Commanding Officer of the vessel, in accordance with Bureau's letter No. 8397-A-45; 409-A; 13181-A-94, of April 27, 1909.

Instruction No. 3. S. & C. Branch, November 16, 1911.

METHOD OF CHECKING RE-MEASUREMENT OF COAL BUNKERS.

Calculations made in accordance with Weight Classification, Supplement No. 1.

Sheet I.—Check computations on this sheet. See if the "Additions" and "Deductions" are correctly brought forward from Sheet II. The capacities of telescoping coal chutes when in stowage position and the capacities of escape trunks should be included in the total capacity, but should be stated separately, in order that it may be readily deducted when they are not filled. (See 1603-A-18; 3037-A; 13181-A-180, March 31, 1910.) If there is a sloping protective deck, note to what line the "Deductions to bottom of beam" are made. Compare with sister ships if available.

Sheet II.—See if the items and totals look reasonable.

Sheet III.—See if gauge marks are at the 100 or 200 cu. ft. levels and that they do not fall within 6 inches of each other. Check several of the distances from reference points. There should be a sheet for each bunker. Note how the top gauge capacity agrees with the capacity given in Sheet I and whether the tanks are included in gauge capacity.

Sheet IV.—See if capacities in cu. ft. are correctly transferred from Sheet I and that the reductions to tons at 43 cu. ft. are correct. Check the addition of column for official capacity. See if the other ton items look rational.

Note if the Constructor states, in the letter forwarding the calculation, that the Commander-in-Chief and the vessel have been furnished copies.

Check from the tracing which should be furnished the Bureau.

If the calculation is found to be correct, date and initial and have a blue-print made of Sheet IV for "Ships Information" before filing.

If the corrections are necessary or if not in the form required, the calculation should be returned for revision.

In this case the instruction card simply says:—"Standard Instructions No.——."

This standard planning has been carried out in a number of important matters.

In design work the planning is assisted by a book of standard procedure developed over a considerable number of years.

The planning comprises for each individual design:—

(*a*) Analysis into component jobs in both rooms.

(*b*) Estimated curve progress on plans on a basis of time.

(*c*) Estimated curve progress on specifications on a basis of time.

(*d*) Estimated curve progress on calculations on a basis of time.

The above, of course, all applies to the actual design after the preliminary work has been done and the type decided on.

Preliminary work has been much facilitated by the use of forms, standard curves and compiled data, but being to some extent in the nature of experimental work is not subject to the exact planning possible in the later stages.

Curves and Charts.—In making these curves reference is had to previous date for similar jobs, foreseen interruptions allowed for, allowance made for leave required by law, sickness, etc.

A sample of such a curve is shown on Plate 28. On this estimated progress curve, which is kept in view, is plotted the actual progress from time to time so that direct comparison and estimates may be made as to the degree of completion, probability of finishing at time set, necessity for overtime work, etc.

One of our most difficult problems arises from the fact that until the naval bill passes we never know what the program for the year is to consist of.

Usually we have sufficient information from the Secretary of the Navy's requests of Congress to approximate to it and to plan the work on the component units, but as soon as the bill passes we must fit these units together, according to the number given us, into a plan for the whole program.

A part of a chart for such a program is shown on Plate 29.

At each leading man's desk is kept a chart on which is indicated currently by red and blue areas the proportion of each component of the job that has been completed. These areas are based on a total area representing 100 per cent and are so made that, by inspection, an immediate glance shows within 5 per cent of the correct amount completed. A sample is shown on Plate 30.

For ship design and ship calculation we have deduced a standard chart; for lesser jobs we either make a special chart or do without it.

JOB ORDERS FOR JULY, 1912.

OH-1—General supervision.
OH-2—Compilation of data.
OH-3—Experiments not covered by specific J. O.
OH-4—Drawing room files.

DIVISION A. PRELIMINARY DESIGNS.

A-17—Repair ship, 1913.
A-18—Scout, 1913.
A-19—Submarine tender, 1913.
A-20—Destroyer tender, 1913.
A-21—Fuel ship, 1913.
A-22—Ammunition ship, 1913.
A-23—Mine ship, 1913.
A-24—Transport, 1913.
A-25—Submarine, 1913.
A-26—Armored cruiser, 1913.
A-27—Laurenti cruiser, 1913.
A-28—Battleship cruiser, 1913.
A-29—Submarine (Flotilla Board characteristics).

DIVISION B. CONTRACT DESIGNS.

B-14—Gunboat No. 19, Sacramento; re-design.
B-16—Battleship, 1913.
B-17—Destroyer, 1913.

DIVISION C. MISCELLANEOUS DESIGNS.

C- 2—Caisson target.
C- 3—Lamson hoist.
C- 4—Standard plans, including leaflet specifications published by S. & A.
C- 6—Worden gyroscope experiment.
C- 9—General specification revision.
C-10—Conversion of Vestal to repair ship.
C-12—Uruquay collier.

DIVISION D. CRITICIZING PLANS.

D- 3—Arkansas.
D- 4—Wyoming.
D- 5—Texas, No. 35.
D- 6—New York, No. 34.
D-13—Jarvis, No. 38.
D-14—Henley, No. 39.
D-15—Beale, No. 40.
D-19—Elec. Boat. Co. submarines, F-3, F-4, H-1, H-2, and H-3.

DIVISION D (Continued).

D-20—Lake submarines G-1, G-2, and G-3.
D-21—Laurenti submarine G-4.
D-23—Jupiter.
D-24—Oil barge.
D-25—Submarines K-1 to K-4.
D-26—Tug. No. 12 (Sonoma).
D-26½—Tug No. 13 (Ontario).
D-27—Collier No. 9 (Proteus).
D-27½—Collier No. 10 (Nereus).
D-28—500-ton coal barges.
D-29—Collier No. 11 (Orion).
D-29½—Collier No. 12 (Jason).
D-30—Cassin, torpedo boat destroyer No. 43.
D-31—Cummings, torpedo boat destroyer No. 44.
D-32—Downes, torpedo boat destroyer No. 45.
D-33—Duncan, torpedo boat destroyer No. 46.
D-34—Aylwyn, torpedo boat destroyer No. 47.
D-35—Parker, torpedo boat destroyer No. 48.
D-36—Benham, torpedo boat destroyer No. 49.
D-37—Balch, torpedo boat destroyer No. 50.
D-38—Submarines K-5 to K-8.
D-42—Nevada No. 36.
D-43—Oklahoma No. 37.
D-44—River gunboat Monocacy.
D-45—Submarine tender Niagara.
D-46—Torpedo testing barge.

DIVISION E. CURRENT WORK.

E-1—Ships in commission.
E-2—Miscellaneous current work; to include requisitions and allowance lists not possible to charge to a specific job order.
E-3—Information prepared for use outside the Bureau, not incorporated in official correspondence.
E-5—Small boats and yard craft.
E-7—Yard plant.
E-9—Ships' data; statistical information relative to ships.

807-L/V—Leave.

Mr.

The information for the record curves is deduced from the component elements on the current chart. The chart being always visible keeps in the mind of the leading man or the inspecting officer where hitches are liable to occur in completing on time.

The last analysis generally reduces to determining whether leave must

be cut off or overtime work adopted, as we try never to exceed an original estimate of time unless directed by the Department.

This system has been found of great value in reducing the necessity for overtime work.

Charges.—The cost of all work is charged to job orders divided into groups.

A copy of the job order division is shown on page 42.

Each employee turns in to his leading man a time card charging his time to the nearest one-eighth day. These cards are checked by the leading man before being turned in. The record of charges is kept by the Bureau's financial section, which is outside this division, but a monthly summary of expenditures under the proper heads is sent to the writer's desk and by him entered on a comparison chart for his own use.

Routing Out.—When the work is completed it must be issued. Checking and instructing has, as shown, gone on continuously during the progress of the work. All calculations of importance are made by two independent men in addition to being checked by a third.

In going out the work goes by regular messenger service to the head of the branch, to the chief draughtsman, and to the office, by all of whom it is checked, and the letter or letters read and the reference slip initialed. All plans and all class (*c*) and (*d*) letters are checked by the writer personally.

Letters and plans finally go to the chief constructor for signature.

The reference slip filed with the letter remains for all time a record beyond dispute as to the responsibility for the action taken.

Record copies of all plans and specifications as produced and signed for issue are filed in the vault at the Navy Yard in order that any change subsequently made may, by comparison with the original, be definitely determined.

Changes of importance is finished plans have been practically eliminated or reduced to a very small number.

General Specifications.—With regard to specifications, it should be stated that some four years ago we formulated the idea of reducing to writing in the form of general specification all general instructions as to work applicable to all navy ships.

The specifications for an individual ship will thus be reduced to a table of scantlings and the particular instructions applicable to that ship alone.

The necessities of the case and the inability to do all we wanted to at one time made the original issue of these general specifications in three volumes, two volumes having to do with instructions for work, methods, etc., and the third being appendices: steel specifications, rivet rules, painting rules, etc. These last were also printed in pamphlet form for individual distribution.

These general specifications, having been in force now about four years, have been supplemented and changed and some items eliminated. As their original form was somewhat cumbersome, we had in February, 1912, a conference attended by all superintending constructors for ships building on east coast, and representatives of all shipbuilders, and the Bureau officers, and we expect shortly to get out a revised and reduced edition of the same specifications in one volume for handier reference.

The use of these general specifications has proved of value. They serve to standardize practice between various building yards, serve as a guide to superintending constructors in matters under their jurisdiction, form a valuable book of reference for repairs and overhauling, and they reduce the time required to get out the detail specifications of a given ship to about one-half that formerly required, besides preventing many errors.

Suggestions.—One of the most important functions we have to perform is keeping a record of suggestions for improvements and changes in specifications, types of ships and their details.

In order to keep track of the changes allowed in building and the changes and improvements found desirable as result of experience in service, it is required that each officer and employee make out a card similar to that shown below for every such item that comes to his notice in any way. He

NEW DESIGN MEMO

TAKE TO—		CONSIDER FOR—		SUBJECT:
N. C. Robinson		BATTLESHIPS		
Chf. Drafts'n		TBD's		
Mr. Wallace		COLLIERS		
Mr. Brill		AUXILIARIES		
Mr. Anderson		SUBMARINES		
Mr.				
REC'D BY SPEC. DESK		ALL TYPES		
		GENERAL SPEC		

REFERENCES

SHIP

LETTER, C. & R. No.

PLAN, C. & R. No.

RECORD OF ACTION TAKEN

N. C. R. 134

CARD MADE BY

DATE

drops the card in the messenger's box, after which it follows the route indicated in upper left-hand corner until it finally arrives at the specifications desk, where it is filed under a proper heading to be considered for the next design. Similar cards are received monthly from all superintending constructors' offices and from construction officers at navy yards.

The most frequent sources of such cards are:—

(*a*) New ideas.
(*b*) Technical publications.
(*c*) Trial board reports.
(*d*) Suggestions from fleet.
(*e*) Suggestions from superintending constructors.
(*f*) Suggestions from builders.
(*g*) Miscellaneous suggestions from any and all sources.

These cards are filed as general, and by types, both under subject index, and whenever a new design is taken up all the cards referring to that time and all the general subject cards are considered.

Ships' Specifications.—In preparing detail specifications for ships first a skeleton form is made. This skeleton is filled out by the specifications desk in consultation with the plans as they progress, with the general specifications and with the specification cards referred to.

This typewritten specification is read and criticised:—

(*a*) By the employee preparing the special plan involved.
(*b*) By the subject specialists concerned in the criticism branch.
(*c*) By the head of the branch.
(*d*) By the chief draughtsman.
(*e*) By the writer and by one or more of his office assistants.

When these notes are all in, a conference is held of all those who have read the specifications. The suggestion cards are gone over, various opinions are voiced and explained, decision made by the writer, and the specifications are ready to print.

After printing, the galley proof is referred to other bureaus for comment, is again checked and discussed in conference, and is finally printed.

Specifications are filed by ship and by number in a storeroom specially assigned.

Issues are made by order signed by the employee in charge of the specifications desk, who keeps the record account of issues and balance on hand.

Each specification contains detachable receipt which must be signed by the recipient and which is filed as the record.

Weekly Conferences.—Once a week, on Wednesday at 9.30 A. M., the officers and the civilian head of the criticism branch (who is the chief

draughtsman), the civilian head of the design and scientific branch, the leading draughtsman in charge of the design plan room, and the electrical aide, meet in the office for a conference.

This generally lasts for one-half to one hour, and at this time we discuss organization, changes in methods and order of doing work, lines of investigation, the best manner of carrying on work, but as a rule no details of work on ships. Discussion as to work on ships is done at special meetings held from time to time or in the workrooms with the individuals. Suggestions as to improvements in methods or on any other subject pertinent to the work of the Division are invited from all employees and officers.

Unfortunately no money reward can be offered for those of value, but credit on the efficiency records is given and the *esprit de corps* is such that frequent and valuable suggestions by employees are made.

The endeavor has been made to give each employee an assignment to temporary duty in the line of his specialty outside of Washington at least once a year, when opportunity arises. This is done with the idea of broadening the point of view of the employee and facilitating his keeping in touch with methods in the yards and manufactories.

The system outlined above is a development of many years of experience in this character of work, and the writer claims no special credit for it.

The fundamentals of the organization were determined under a former president of this Society when he ably held the position of Chief Constructor of the Navy. The division, since these fundamentals were determined, has been under Mr. H. G. Smith, now manager of the Fore River Shipbuilding Co., and Mr. H. S. Ferguson, now general manager, Newport News Shipbuilding & Dry Dock Co. To these gentlemen much of the development is due.

The development has gone on under the writer's immediate direction during the incumbency of Chief Constructor Capps and his successor, the present Chief of Bureau, Chief Constructor Watt.

The credit, if any, is due as much to the individual employees as to any one, as through their suggestions many, if not most, of the improvements have been made.

No special advocacy is made as to the application of this system to the problems of others. Indeed it may not be suitable for others, though it suits our case well.

The keynotes are simplicity and order.

Its result, though we hope for further improvement, is efficiency.

DISCUSSION.

THE PRESIDENT:—Gentlemen, you have heard the paper just presented by Mr. Robinson on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department." This paper is now before you for discussion.

NAVAL CONSTRUCTOR JOSEPH H. LINNARD, *Member of Council:*—On page 41 of his paper Mr. Robinson remarks: "One of our most difficult problems arises from the fact that until the naval bill passes we never know what the program for the year is to consist of." Many of the members of this Society may be unaware that for several years past every naval appropriation bill providing for an increase of the Navy has at the same time contained a positive prohibition against using any of the money appropriated for the increase of the Navy for the design of the vessels. Other appropriation bills limit to a specific fixed sum, which has not been increased in any material way for a number of years, the amount that can be paid for employees, both draughtsmen and clerical, who can be used in the Navy Department in Washington, whose numbers are thus virtually fixed. As you all know, the work devolving upon the Navy Department in connection with not only the designing of ships, but the running of them and their management, has enormously increased as the years have passed, and the problem that Mr. Robinson and others have been up against has been how to accomplish this greatly increased work with the same force of draughtsmen and clerical employees.

As Mr. Robinson has explained in his paper, success has been reached through the employment of methods and the study of the processes of work, which have been frequently called by that much abused term, "scientific management;" but this is a case in which the management, and the arrangements and studies which have been made in the work, and which have produced such remarkable results, have been made with the same working force, so that the criticism sometimes made against "time studies" and similar methods that while reducing the number of employees in certain directions they require additional employees of one kind and another which offset the saving supposed to be made, cannot apply here, because we have not been able to increase the total force, and therefore I thought I would make it clear to you that these studies to which Mr. Robinson referred have produced more work with the same force of employees, and therefore they could not be considered otherwise than as a success.

THE PRESIDENT:—Is there any further discussion?

MR. HOMER L. FERGUSON, *Member of Council:*—Mr. Robinson very modestly says that he will leave the results of the work which he has been doing in Washington

to be judged by others. This question which he has brought up and discussed has particular interest to people in our business, I take it, in two ways; one is in the results produced, which have been most excellent; and the other in its bearing on improvements in general office and draughting-room method. I do not think there is any draughting or office force in this country, either in the government service or outside, which in efficiency and in promptness and in actual knowledge of what they are doing exceeds that of the force under Mr. Robinson, and those of us who do business continually with various governmental departments and with various organizations outside know that work which goes there is dealt with most promptly and most effectively, and if you get turned down it is done emphatically and at once without holding you up for a long time. I think that the results in that direction have been very remarkable, and I regret to state, in a way, that most of them have been accomplished since Mr. Robinson succeeded me in the job.

As indicating what can be done with an office force, I think it is very instructive to anyone who is interested in scientific or common-sense, or any other form of management—which, of course, is what all of us who are trying to manage something should continually try to adopt—we should try to do things in an easier and better way, and with more method, and in my judgment there is greater room for improvement in most offices, in most drawing rooms, than there is in most work. In my experience, efforts at scientific management have usually been aimed at correcting the evil habits of some one outside of the main offices, and I believe that in the offices is the proper place to begin.

Chief Constructor R. M. Watt, *Vice-President:*—Naval Constructor Linnard might have referred to another phase of the subject—that, while appropriation bills vary in amounts appropriated, they seldom vary in numbers of types of ships required, as was evidenced by the last appropriation bill, thus throwing practically the same work on the design branch of the bureau when appropriations are small as when they are large.

As chief constructor, I desire to express my appreciation of the system which has just been described, for under the able administration of Naval Constructor Robinson it is unquestionably producing results.

The President:—Is there any further discussion? Does Mr. Robinson wish to close the discussion?

Mr. Robinson:—I was not fishing for bouquets when I wrote this paper. I appreciate the complimentary things which have been said, nevertheless.

With regard to what Mr. Linnard said, I may say that we have one less employee now than we had ten years ago, so that his statement is correct. As a matter of fact our money expenditure is the same now, but we have distributed the expense of one man over the balance of the force. The original reason I had in mind in preparing this paper was because I am very much interested in system, and while I

have a very small force to organize and manage, I spent most of my spare moments in doing that, and I put it down here in the hope that in the years to come other people would give a statement of what they had been able to do. I believe there are two important parts of the engineer's business; one is the technical and the other is the mangerial, and when I get tired of one, I turn around and do the other. Any information which may be contained in this paper is simply the result of the compilation of methods which have been applicable to the case in point.

Mr. Spencer Miller, *Member:*—I want to move a vote of thanks to Mr. Robinson for his valuable paper, and for the time he must have spent in the compilation of it.

The President:—The only regret I have about the matter is that there are not many more shipyards to need this admirable arrangement of their drawing-room forces.

The meeting now stands adjourned until 2.15 this afternoon.

Thursday Afternoon, November 21, 1912.

The President called the meeting to order at 2.20 P. M.

The President:—At the meeting of the Council yesterday afternoon a committee was appointed to draw up suitable resolutions in regard to the death of Past-President Clement A. Griscom, and I call upon Mr. Lewis Nixon, the chairman of the Committee, to make his report.

Report of Special Committee on Resolutions Relating to the Death of Clement Acton Griscom.

Mr. Nixon:—Mr. President and gentlemen, the special Committee of the Council appointed by the President reports the following minutes and resolution, and move that they be adopted by a rising vote:—

"It is with deep sorrow that the Council reports the death of Clement Acton Griscom, Past President and Honorary Associate Member of this Society, and who from the date of his election as our first president has been its constant and active friend.

"He freely extended his great energy and ability to the establishment of the Society as a permanent influence in the field of marine engineering and shipbuilding achievement.

"His services to this Society and to the shipbuilding and shipowning interests of the United States were but a single instance of his energy and capacity which, combined with great executive power, forcefulness of purpose and lofty vision, aided so greatly in the commercial development of our country and in the perfection of transportation on land and sea.

"The Council moves the adoption of the following resolution:—

"'That the Society of Naval Architects and Marine Engineers directs that this expression of admiration for the character and achievements of Clement Acton Griscom, of its gratitude for his manifold services to this Society and of sincere regret over his death, be spread upon our records, and that a copy of the same be sent to his family.'"

The resolution was then put to a vote, and it was unanimously adopted, all members rising.

The President:—We will now have the paper entitled "Engineering Progress in the U. S. Navy," by Capt. C. W. Dyson, U. S. N. In the absence of Captain Dyson, the paper will be presented by Admiral Cone, Engineer-in-Chief, Chief of the Bureau of Steam Engineering, of the Navy Department.

Admiral Cone presented the paper, and in connection therewith made the following comments:—

"Page 59, under 'Conditions.' I think Captain Dyson is in error there. I am informed that the Delaware did not win the championship, but the Colorado won the championship and the Delaware was next.

"Page 60. In connection with the statement, 'This system, as applied to the destroyers, depends entirely for its gain upon the greater efficiency of the reciprocating engine at the higher steam pressures over the efficiency of high-pressure turbines of the reaction and the high-pressure nozzles of the impulse type of turbines, no advantage being gained from increased efficiency of propellers, as the reciprocaing engines are on the same shafts as the turbines. From some points of view this combination is undesirable, and the gain in service must be considerable to justify its retention.' I do not know when this was written. Recently the system has been tried and has met everything that was expected of it."

ENGINEERING PROGRESS IN THE U. S. NAVY.

By Captain C. W. Dyson, U. S. N.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

In preparing an article under the heading of "Engineering Progress in the U. S. Navy," the ground to be covered is of such large extent that, in the greater part, nothing but the merest notice of improvements can be given, and only the most important points of progress will be detailed. The first and most important point of all, as reacting upon the general efficiency of the Navy as a reliable and economical fighting force, is the—

CHOICE OF PROPELLING MACHINERY FOR HEAVY VESSELS OF MODERATE SPEED.

In the selection of the type of machinery to be used in the above class of vessels, the following points must be taken into consideration:—

(*a*) General character of the service which the vessel will be called upon to perform; whether she must keep the sea for long periods, cruising at speeds very much lower than her maximum speeds, or whether she will be called upon for very little slow cruising, but shall be held in readiness for dashes at high speed from a base to any threatened point.

(*b*) Greatest economy realized at the conditions under which she will be called upon to operate. This point is important, not only from the point of financial saving in reduced fuel cost, but in the greater ease of fuel supply due to the decreased demands.

(*c*) Fuel capacity entailed by the demands of the service to which the vessel may be subjected.

(*d*) Ease of up-keep of the machinery, and degree to which the vessel, so far as machinery repairs are concerned, can be made self-supporting.

(*e*) Reliability of machinery when driven at high powers.

(*f*) Minimum weight and space required for the propelling machinery.

(*g*) Efficient propellers for maneuvering.

(*h*) Minimum of vibration of hull due to machinery in operation.

(*i*) Effect of vertical position of center of gravity of the machinery upon the time of roll of the vessel, in fixing the quality of the vessel as a gun platform.

The question of costs of the different types of machinery will not be considered in comparing the relative advantages of the types.

Further, the relative values of turbine reduction gear, electric propulsion and internal combustion engines for propulsion will not be dealt with, for the following reasons:—The turbine reduction gear and electric propulsion are under trial in the naval service at the present time, the reduction gear being actually afloat while the vessel fitted with electric propulsion is building.

The results obtained up to date with the reduction gear have been disappointing so far as the expected economy is concerned, the results being vitiated by faulty turbines and too high a number of revolutions of propeller, 135 per minute, for the type of vessel and the speed, 14 knots. The reduction gears have, however, stood up to the work well and show practically no evidences of wear. Results are encouraging and a great improvement is expected when contemplated changes in the turbine have been made.

Electric propulsion not having been tried out in actual service, it is considered preferable to content ourselves with the mere statement that shop tests of one of the units have been very gratifying and promise a successful end to the experiment, so far as economy of propulsion only is considered.

As to the question of propulsion by internal combustion engines, where large powers are required, there appear still to be many important problems requiring solution before units of sufficiently high powers for the purpose desired can be built. The supplanting of the steam-engine, both reciprocating and turbine, for important high-power installations does not appear to be imminent in the immediate future.

Eliminating these three latter methods of propelling naval vessels restricts the choice of machinery for this purpose to the three following methods:—

1. By means of reciprocating engines.
2. By means of steam turbines, impulse, reaction, or a combination of the two.
3. By means of various combinations of reciprocating engines with turbines.

COMPARATIVE SUITABILITY OF EACH OF THE ABOVE METHODS FOR NAVAL PURPOSES.

To assist in reaching a decision as to which of the three methods of propulsion best meets the requirements lettered from (*a*) to (*i*), a comparision of the performances of the dreadnoughts Delaware, North Dakota, Utah, and Florida can be made; these performances include those on preliminary acceptance trials and those in actual service.

On Plate 31 are given the indicated horse-power speed curve of the Delaware and the shaft horse-power speed curves of the North Dakota, Utah, and Florida.

In comparing these curves it should be noted that, due to differences in displacements and in appendages, the effective horse-power required to give the Delaware a speed of 21 knots will give the Florida and the Utah 20.82 knots, and the North Dakota 21.1 knots; at 12 knots for the Delaware, the equivalent speed of the Florida and the Utah is 12.17 knots and of the North Dakota 12.1 knots.

Assuming that shaft horse-power is approximately 92 per cent of indicated horse-power in large, well-designed reciprocating engines, and reducing the indicated horse-power of the Delaware to shaft horse-power, the following table of comparison results:—

	Delaware.	*North Dakota.*	*Utah.*
Speeds of equal E. H. P.'s	21	21.1	20.82
I. H. P. for this speed	23,400	——	——
S. H. P. for these speeds	21,528	27,150	25,000
Propulsive coefficient equals (per cent)			
E. H. P. ÷ S. H. P	71.76+	56.8+	61.8+
Cruising speeds of equal E. H. P	12	12.1	12.17
I. H. P. for this speed	3,600	——	——
S. H. P. for these speeds	3,312	3,825	3,975
Propulsive coefficient equals (per cent)			
E. H. P. ÷ S. H. P	74+	64.1+	61.6+

While the Florida curve is shown on Plate 31, that vessel is not included in the above table, as the weather conditions during her standardization trials were unfavorable and the efficiency of the propellers fell off greatly, due to these adverse conditions. This excessive falling off in efficiency of propulsion under adverse conditions of wind, sea and of ship's bottom are characteristics of turbine-driven vessels, and affect requirements (*a*) (*b*), and (*c*) to a large degree.

Formerly, the favorite method of comparing the relative economies of propulsion of reciprocating engines and turbines was by comparing the water per shaft horse-power of the turbines with the water per indicated horse-power of the reciprocator, in this comparison all mention of the large difference between the indicated horse-power required in the one case and the shaft horse-power in the other being carefully neglected.

The method of comparison in use to-day is the commercial one of "pounds of fuel per knot" at different speeds, and it is on this basis that the curves shown on Plate 32 are constructed.

CONDITION OF PLATE 2 CURVES.

Curves A, B and C.—Actual trial conditions.

Curve D.—Using same feed temperature conditions as for Curve C.

Curve A.—Feed heaters not in use.

Curve B.—Feed heaters in use.

Curve C.—Feed heaters in use. Feed temperature much higher than A and moderately higher than B.

As practically the same amounts of heating medium for the feed heaters were available in each case, it is justifiable to correct the British thermal units absorbed by the boilers in A and B, by the amount of decrease due to the higher feed temperature of C.

Boilers in all cases were of the same type, but for A and B they were fitted with superheaters.

Boilers being of the same type they can be assumed of the same efficiency, therefore the actual efficiency may be neglected and a boiler efficiency of 100 per cent be used for comparison of performances without sensible error in the comparison.

Curve B is not exactly comparable with Curves A and C, as it does not include full expenditures for all purposes as do the others, and hence it has not been reduced to equal feed conditions with C.

In preparing A, B, C and D, the following formula has been used:—

$$\text{Pounds coal per knot per hour} = \frac{(T-(t-32))\times W}{S\times 14500},$$

where

T = Total heat in steam at boiler pressure and superheater.

$t-32$ = Feed temperature above 32° F.

W = Total water evaporated per hour.

S = Speed of ship in knots per hour for which W pounds of water are evaporated.

14,500 = Thermal value of one pound of coal.

On this plate is also shown a curve of excess fuel for the Utah over that required for the Delaware, all the curves being drawn with effective horse-powers as abscissæ.

For the effective horse-power value required for 12 knots speed of the Delaware, the Utah requires, by these curves, 22 per cent more fuel. From the steam logs of the two vessels, the average excess fuel consumption of the Utah over that of the Delaware at 12 knots is 20 per cent, thus corroborating the results obtained from Plate 2.

At the effective horse-power value required for 21 knots by the Delaware, the Utah requires 1.015 times as much fuel as the Delaware, a difference so light as to be negligible.

From the above results, it appears justifiable to decide as follows:—

Should the duties of a vessel be such that she be required to steam for long periods and long distances at speeds much lower than her designed maximum speed, a less fuel expenditure per day will be required, and consequently a greater cruising radius will be obtained and less frequent recoaling necessitated should reciprocating engines be fitted rather than turbines for propelling purposes.

Should, however, the vessel operate from a fixed base, only doing sufficient cruising to insure that the machinery is kept in efficient condition in readiness for forced runs to any threatened point, the value of fuel economy at low speeds becomes minimized and, where the maximum speed of the vessel does not exceed 21 to 22 knots, either turbines or reciprocating engines may be used, the choice being dependent upon other factors than economies, which are practically equal at these speeds.

In other words, for the conditions (*b*) and (*c*), under which the American battleship fleet operates, the reciprocating engine is preferable to the turbine as a propelling engine at the present stage of turbine development.

The Navy Department is, however, thoroughly alive to the advantages to be gained by adopting rotary in place of reciprocating motion in the main propelling machinery of the heavy vessels of the fleet, and, while recognizing the present advantages held by the reciprocating engine in the matter of economy at low fractions of designed power, holds itself ready to discard the reciprocating engine as soon as the turbine designers can demonstrate by actual performance that their claims as to equality of economy at low powers with the older machine have been realized. It was with this object in view that the department decided to install impulse turbines in the Nevada, and not because the engineers of the department were "wobbling," as has been charged.

Condition (d)—Ease of Up-keep of Machinery.—The claim is frequently made by the turbine advocates that while the reciprocating engine, when new, is undoubtedly more economical than the turbine at small fractions of designed power, this advantage is soon lost in active service, due to excessive wear of piston and valve rings causing large losses through heavy leakage of steam. The turbines, not being subject to such frictional wear, would, on the other hand, retain their original economy indefinitely.

Practical experience with both types of engine in actual service comes very far from justifying this conclusion. In fact, with intelligent super-

vision, the reciprocating engine, particularly since forced lubrication has been applied, holds its superiority continuously.

When reciprocating-engine vessels visit the navy yards for their regular overhaul, the work to be done on the main engines is practically nil, as the machine shops and foundries of the battleships are of ample capacity to take care of all repairs that may be necessary except such as the fitting of a new cylinder or the repair of a fractured bed-plate. The above remarks apply only, however, to ships fitted with forced lubrication, where the wear of bearings and journals has been practically eliminated.

In a letter from the senior engineer officer of the Delaware, the following statements occur:—

"January 26, 1912. Examined on each engine one main journal, one cross-head, and one crank-pin brass and found all in good condition. On passage from New York to Guantanamo Bay, during a heavy gale a quantity of sea water entered the crank pits but no trouble was experienced although we ran at 19 knots, lubricating with a mixture of 40 per cent oil and 60 per cent sea water."

"Report B. Recently leads have been taken off several cross-heads, after about 30,000 miles steaming without inspection or adjustment, and they have been found in excellent condition with practically no wear.

"Between July 1, 1910, and July 10, 1912, the Delaware has steamed 54,627 miles (knots) without a hot bearing.

"About the only wear on the brasses on the forced lubrication system is on the cross-heads, first, then guides and then crank pins. The wearing away of the piston rings apparently starts all the other wear."

That is, keep the pistons in line and the wear on the running parts is practically eliminated.

These experiences of the Delaware are not unique but are corroborated by the experiences of every reciprocating-engined vessel of the fleet to which forced lubrication has been applied. This system not only ensuring efficient lubrication, but also reducing wear on all running parts, decreases the initial friction of the engines and reduces to a minimum all shock on crank pins, cross-heads and main bearings, thus preventing hammering out of the white metal and all wearing down out of line.

When we turn to the turbine engines, however, the case is quite the opposite. Fully 99 per cent of the troubles that occur with this type of engine are internal troubles, and consist of erosion of blades and nozzles, stripping of blading, heavy corrosion of rotors, diaphragms and turbine wheels, causing destruction of balance. All of these troubles require a perfectly smooth haven in which to make repairs, and the majority of them require dock-yard facilities.

In the cases of the main engines of the three scouts, Birmingham, Salem, and Chester, the Birmingham, with reciprocating engines, has always been ready for service, while her two sisters have been repeatedly laid up at the yards for overhaul of the main turbines.

Evidence of experience leads to the conclusion that a battleship fitted with reciprocating engines for propelling purposes is much less apt to be forced off her station by necessary repairs to her engines than is one fitted with turbine engines.

Condition (e)—Reliability of Machinery when Driven at High Powers.—From the natures of the two machines, it would appear to be safe to decide this condition as being distinctly in favor of the turbines, as this type of engine is completely free from all reciprocating parts held together by bolts and nuts.

Experience with the Delaware's engines, however, leads to the conclusion that where proper care is taken to lock all nuts securely, and to effectively protect the engines against the shocks of reversal of direction of motion, the reciprocating engine can, even here, be regarded as nearly on a par with the turbine in reliability.

The full-power twenty-four hour run of the Delaware, made without preparation immediately after her arrival home from Chili, demonstrates this reliability of the present type of battleship engines very thoroughly. As stated, without any preliminary preparation of engines or machinery, the vessel put to sea, and upon getting well clear of the land a full-power run of four hours was started, during which time the vessel averaged 21.86 knots per hour. Without intermission the vessel continued on for twenty hours longer, averaging for the full twenty-four hours a speed of 21.3 knots, the ship automatically slowing down as the fires became dirty and the personnel fatigued.

Upon the completion of the trial a radiogram was received from the commanding officer of the vessel reporting that not the slightest disarrangement had occurred to either the main engines or the auxiliary machinery, and that she was ready for immediate service.

Condition for Minimum Weight and Space Required for the Propelling Machinery.—As already shown, the total heat units required to be absorbed by the boilers, both for Parsons turbines and for reciprocating engines, with battleships of the speed and power that now exist, is practically the same in both cases at full power. This indicates that, for existing conditions, nothing can be saved in the boiler-room weights or space by adopting turbines, as the same boiler power is required in the two cases.

In the engine-rooms, for these powers, however, the reciprocating engine has a decided advantage in both weight and space required.

Thus, in the Delaware, North Dakota, and Utah, the engine-room weights and space required are as follows:

	Delaware.	*North Dakota.*	*Utah.*
Engine-room weights, dry tons.....	728.26	731.23	864.69
Engine-room weights, wet tons.....	773.26	785.93	919.80
Engine-rooms, length.....	44 feet	44 feet	60 feet
Engine-room total width.....	50.5 feet	50.5 feet	51 feet
Engine-room, square feet, floor space..	2,222	2,222	3,060

While the turbines of the North Dakota appear to be about on an equality with the reciprocating engines of the Delaware in the matters of weight and space, these turbines were extremely uneconomical. Modern turbines of this type would require an engine-room more nearly equal in length to that of the Utah, and the engine-room weights would be considerably increased.

While the reciprocating engine has a decided advantage in the features of weight and space required, under present conditions, these advantages would disappear should the necessary power to be developed be increased considerably above what is now asked for, and the advantage would rest with the turbine. Should such an increase of power be called for in future designs, or should the ordinary cruising speed be made considerably higher than now used, the Navy Department would undoubtedly abandon the reciprocating engine and adopt one of its rotary rivals for the propulsion of its capital ships.

Condition (g)—Efficient Propellers for Maneuvering.—In considering this condition, the relation of the backing powers of the vessel as compared with the maximum full power ahead, and the time required from full speed ahead until the vessel is dead in the water, will be taken as a comparative measure of this condition.

On Plate 41 are shown curves of indicated horse-power for backing for the Delaware and of shaft horse-power for backing for the Salem, the abscissæ values being indicated horse-power and shaft horse-power in the ahead motion. At the low abscissæ values, where more boiler power is always available than is necessary for the actual ahead speed being used, the backing power exceeds very considerably the ahead power in use, as when backing for short periods the throttles can be opened wide and the boiler power available be made use of.

When all boilers are in use, which in the case of the Delaware occurs at 25,000 indicated horse-power for the main engine in the ahead motion, and for the Salem at 14,000 shaft horse-power for the main engine in the ahead motion, the maximum backing powers can be obtained. In the case of the

Delaware this maximum backing power amounts to 89.2 per cent of the ahead power, while in the turbine vessel Salem it amounts to only 41.9 per cent. That is, at these points, the backing power of the Delaware is 2.13 times as great as that of the Salem (both being expressed as fractions of the ahead power).

At the maximum powers developed by the engines of the two vessels, the ratio of the percentage backing powers becomes:—Delaware = 2.27 Salem.

These results are further corroborated by the backing tests of the Delaware and the Utah upon their preliminary acceptance trials, where, with the Delaware going ahead at 21 knots and the Utah at 20, the times taken to bring the vessels dead in the water were, for the Delaware, 1 minute 52 seconds; Utah, 4 minutes 44 seconds.

	Delaware.	*Utah.*
Backing power divided by ahead power...	87.5%	35.7%

These results are still further corroborated by the destroyers. These vessels can easily steam ahead at 16 knots under one boiler, but when called upon to maneuver they invariably, as a matter of safety, start a second boiler.

Conditions (h) and (i)—Minimum Vibration of Hull; Steadiness of Hull as a Gun Platform as Affected by Machinery.—In judging these points it seems only fair to base the decision upon the results of target practice of the vessels in service. If this is done, the decision could be given to the reciprocating type of machinery, as the Delaware has just won the championship of the battleship fleet, with the Colorado, another reciprocating-engine vessel, standing second on the list.* From these results it appears reasonable to state that, with well balanced reciprocating engines, no ill effects on gun fire should be expected.

CONCLUSIONS.

Basing the choice between reciprocating engines and turbines for battleship propulsion under existing conditions of speed and power upon the above comparison of relative advantages of the two types, the advantage appears to rest most decidedly with the reciprocating engines, and the Navy Department has ruled accordingly (in the cases of the New York, Texas, and Oklahoma).

COMBINATION SYSTEMS.

In the search for economy of propulsion through a wide range of speeds, various combinations of reciprocating engines and turbines have been proposed, both by the Bureau of Steam Engineering and by the shipbuilders,

*The Delaware stood No. 1 in combined gunnery and engineering efficiency, No. 2 in gunnery, the Colorado, a reciprocating engine vessel, standing No. 1.

but only one of the systems has as yet been authorized, and that one is for destroyers. It had not yet been tried out in service, but preliminary shop tests show a good gain in economy of the main propelling engines at cruising speeds. This system, as applied to the destroyers, depends entirely for its gain upon the greater efficiency of the reciprocating engine at the higher steam pressures over the efficiency of high-pressure turbines of the reaction and the high-pressure nozzles of the impulse type of turbines, no advantage being gained from increased efficiency of propellers, as the reciprocating engines are on the same shafts as the turbines. From some points of view this combination is undesirable, and the gain in service must be considerable to justify its retention.*

With the other combination systems proposed, calculations indicate that if the propulsive efficiency counted upon can be obtained, these systems will all be very much more efficient than either a straight turbine or straight reciprocating engine drive at maximum power, will hold a big advantage over the straight turbine drive through all ranges of powers, and will hold its advantage over the straight reciprocating engine drive until a minimum speed of about 11 knots is reached, when the efficiencies become equal.

The "if" exists, however, and is caused by the danger of the currents thrown to the rear by the big reciprocating-engine screws seriously affecting the rate of feed and direction of flow of water to the turbine propellers. In addition, there may possibly be another source of loss due to heavy leakage of steam through the large change valves which must be fitted to control the paths of flow of the exhaust steam from the reciprocating engines.

In all of these systems, to adapt them to naval requirements, it is necessary to exhaust from the low-pressure cylinders of the reciprocating engines at a pressure of not less than 25 pounds absolute, when this engine is operating at full power, and to by-pass as few of the stages of the turbine as possible in order to obtain an increased economy of propulsion through a large range of powers.

TURBINE CHANGES TO PRODUCE INCREASED ECONOMY.

The Parsons turbine as it exists in our vessels to-day is, with very few exceptions, the same as the turbines of this type which were fitted in the initial turbine vessel, the Chester. The only improvements which have been made consist of changes in blade angles, particularly in the low-pressure stages, an increase in the number of rows of blades in these same stages, and the fitting of nozzles for the admission of auxiliary exhaust steam at several different locations along the steam path.

*Since the above was written, this system has been tried and expected economies have been more than realized.

With the impulse turbine, however, the advance over the original naval turbines of this type, those of the scout Salem, has been rapid. The number of stages has been very much increased, both in battleship and in destroyer turbines, a drum construction has been adopted for the lower-pressure stages, steam balance for propeller thrusts has been provided, cruising nozzles for low fractional powers have been fitted, and nozzles for utilization of auxiliary exhaust are now supplied as in the Parsons turbines.

That these changes in turbines of the impulse type have been accompanied by increase in economy has been thoroughly demonstrated by experience with the machinery of the destroyers, the economy of the impulse turbine showing up nearly, if not fully, as good as that of the reaction type. No opportunity has as yet been offered to obtain a measure of this economy increase with the battleship types of impulse turbine, nor will such opportunity occur until the Nevada is ready for trial.

IMPROVEMENTS IN RECIPROCATING ENGINES TENDING TOWARD INCREASED ECONOMY AND REDUCTION IN WEIGHT.

The steps taken in pursuit of the above objects are—

1. Increase in steam pressure at engine.
2. Change in design of engine framing.
3. Increase in piston speed.
4. Use of superheat, but to a small degree only.
5. Reduction of clearances in cylinders.
6. Decrease of frictional losses through steam ports.
7. Positive circulation of steam through steam jackets.
8. Reduced back pressure in low-pressure cylinders.
9. Increased ratio between low-pressure and high-pressure cylinders, with consequent increased ratio of expansion of steam.
10. Application of forced lubrication to all journals, crosshead guides, eccentrics and thrust bearings.

While the following improvements, both with reciprocating engines and with turbines, have been made:—

11. Improved condensing apparatus resulting in higher vacuum.
12. Rational designs of feed heaters based upon amount of water to be heated and amount of auxiliary exhaust steam available for heating purposes instead of using the old rule of thumb of allowing a fixed number of horse-powers per square foot of heating surface.
13. Basing steam-pipe design upon actual rate of flow of steam through the pipes as determined by tests in service.
14. Reduction of feed-pipe losses to a minimum.

15. Improved evaporators and other auxiliaries.

In addition to the above, the reliability of the machinery plant has been improved by—

16. Adoption of high-speed, electric-driven forced-draft fans for battleships.

17. Turbine-driven forced-draft fans for destroyers, and the most important of all—

18. The adoption of oil fuel for both battleships and destroyers.

Considering the above changes in detail, the steam pressures at the main engines since 1895 have been increased gradually from 150 pounds per gage to 265 pounds per gage in the high-pressure valve chest, resulting in decreased size of engine cylinders and in decreased size of steam piping for equal units of power.

The engine framing of the vertical engines first fitted was either of cast steel or built up of steel plates, as shown on Plate 37. On several vessels trouble has been experienced with this type of framing, particularly when made of cast steel, and, in addition, the weight was high. The Bureau of Steam Engineering, in order to overcome these faults, designed and adopted the style of framing shown on Plate 38 for the Kearsarge and Kentucky, and this style of forged steel, built-up framing has been adhered to.

Since the adoption of this type of framing, framing troubles are unknown notwithstanding the fact that the weight of the modern framing per indicated horse-power has been reduced to about 3.3 pounds against $5\frac{1}{2}$ pounds for the old.

Since the design of engines for the Oregon were laid down, there has been a gradual increase in piston speeds used, from 900 feet in that class to 1,000 feet in the Delaware class. This increase in piston speed has been followed by decrease in weight of the moving parts and has aided in holding down the weight and height of the engine, although the stroke has been increased from 42 inches to 48 inches.

On Plate 36 are shown lines giving the maximum and minimum heights of naval engines for different lengths of stroke, also the line of cross-head pin centers and crank-pin centers. These curves are all for engines having the bureau's standard ratio of four to one between the connecting-rod length and crank-pin arm.

In the use of superheated steam, the Bureau of Steam Engineering has been rather conservative; at present there are seven vessels in the naval service fitted for superheat, the maximum degree of superheat obtained at the boilers being 85° F. which reduces to about 60° F. at the engines. These figures are for full-power conditions, and an increase in economy of about

6 per cent is estimated to be obtained. At 12 knots, the cruising speed, the saving by the use of superheat hardly exceeds 3 per cent.

The first experiences with the vessels fitted with superheat were far from satisfactory, due to the rapid deterioration of the valves in the steam lines. These valves had cast-steel bodies and cast-steel valve discs with monel metal seats. The erosion and corrosion of the valve discs was very extensive, and in a short period of service it became necessary to replace the cast-steel valve discs with discs of monel metal. This substitution has been satisfactory and no further trouble has been experienced.

The superheat has been used only on battleships fitted with reciprocating engines or impulse turbines for propelling purposes and has not as yet been used on any of the destroyers.

Reduction of clearances, decrease of frictional resistances of steam through the steam ports and reduced back pressures in the low-pressure cylinders have all resulted from one very important change in the design of engine cylinders and valve chests. The original design of these cylinders is shown on Plate 40, and the modern improved design on Plate 39.

The results obtained by this change from the long, tortuous port to the short, direct port can best be shown by the following table of comparison of cylinder clearances and steam velocities:—

	Old Type.	*New No. 1.*	*New No. 2.*	*New No. 3.*
Diameters of cylinders:—				
H. P.	32½″	38½″	32″	35″
I. P.	53″	57″	52″	59″
L. P.	2–61″	2–76″	2–72″	2–78″
Stroke of pistons	48″	48″	48″	48″
Per cent clearances:—				
H. P.	28	16.17	13.83	13
I. P.	20.8	13.17	12.65	13½
L. P.	18.5	12.485	12.02	12
Steam velocity, feet per minute:—				
H. P.	5,670	6,565	6,723	6,402
I. P.	8,262	6,678	7,883	7,517
L. P.	10,833	10,446	9,947	10,281
Exhaust velocity:—				
H. P.	5,480	5,340	5,289	5,078
I. P.	6,670	6,180	5,909	6,087
L. P.	7,450	7,514	7,199	7,298
To condenser	7,390	6,637	6,612	6,500

To further illustrate the gains made by the short direct ports, attention is called to Plate 33, where the back pressures on the low-pressure pistons of several vessels at varying revolutions are shown as curves, the designed revotions being marked on each curve by a circle. Of these vessels, the Delaware is the only one with the modern type of port.

In the last ten years, the cylinder ratio of low pressure to high pressure, for triple expansion engines, has been increased from about 7 : 1 to 10 : 1, including clearances. This increase in ratio had been used previously in remodeling the engines of the Cincinnati and Raleigh, with most excellent results. A serious mistake was made, however, in counting too much on the increased expansions obtained by fitting a smaller high-pressure cylinder than that originally installed, the steam pressure having been increased. The new high-pressure cylinder was made 24 inches in diameter and the ratio of low-pressure to high-pressure cylinder changed to about 11½ to 1. While the economy obtained with these engines was most excellent, the high-pressure cylinders were entirely too small and the engines have never developed the expected power.

By the adoption of forced lubrication for the main propelling engines, the engine friction has been enormously reduced. All the journals are oil born so that no metal to metal contact occurs. The result has been that the amount of adjustment and overhaul of the main engines has been decreased to a very large extent, and the men who would have been used for this overhaul work can now be used on the auxiliary machinery to good advantage. This decrease in wear of the bearings, and the cushion provided by the oil, has resulted in a much better maintenance of alignment of the engines, has reduced shocks on the machinery and has reduced vibration due to these shocks.

In addition, there is considerable saving in oil at ordinary speeds. At high speeds there still exists a heavy loss of oil, due to splashing on the cylinder heads and also to loss by evaporation from the hot surface of the lower heads.

When first fitted, the forced lubrication gave trouble, due to oil being drawn through the low-pressure piston-rod stuffing boxes. In order to remedy this defect, stuffing boxes fitted with steam seals have been supplied, and later reports indicate that where the steam seal is properly fitted no trouble of this kind now exists.

That the foregoing changes have produced great economy is amply demonstrated by the results obtained with the machinery installations of the Michigan, South Carolina, and Delaware. Plate 33 shows curves of indicated horse-power per square feet of grate surface, and curves of square feet of

heating surface per indicated horse-power for vessels fitted with the new type of engines and with boilers having superheaters, and also for vessels with the older type of engines and no superheat.

In laying down these curves, the actual generating heating surfaces and superheating surfaces have been retained, and the grates have been increased or decreased in order to have a constant ratio of heating to grate surface of 48.5, this being the ratio for the boilers of the Minnesota. At the same time, the air pressures have been corrected inversely as the ratio of the new grates to the actual grates.

The results obtained are shown as follows:—

Curves of indicated horse-power per square feet of grate surface.

A—With moderate superheat and modern engines.

B—No superheat and unimproved engines.

Curves of square feet of heating surface per indicated horse-power.

A—Generating and superheating surface per indicated horse-power with modern engines.

C—Generating surface per indicated horse-power with modern engines and superheat.

B—Generating surface per indicated horse-power with unimproved engines and no superheat.

With the advent of the turbine for marine propulsion, if the full benefit of the new machine was to be realized, a high vacuum in the condensers became imperative. In order to obtain such vacuums, the Parsons Company originated the vacuum augmentor, and this addition to the condensing plant is used extensively in the naval service. In some vessels in the service, in place of the ordinary air pump with augmentor, air pumps of the dual type, as manufactured by Weir, have been fitted, while in other vessels both wet and dry-air pumps have been used.

Of these systems, that with augmentors and also the dual type appear to give the greatest satisfaction in service, and in addition require less weight and space than the wet and dry system. Abroad, a new system, known as the "Kinetic," has been developed, and all reports received concerning it have been very favorable, but no example of this system yet exists in the American naval service. In conjunction with these improved pump systems has occurred an improvement in the tube spacing and the baffling of the condensers in order that a better separation of air from the water of condensation will occur in the condensers.

The improvements in design of feed heaters, steam pipes and feed pipes naturally followed on the measurements of water consumptions of the machinery taken during the acceptance trials of the vessels. These measurements placed in the hands of the Bureau of Steam Engineering data of great value, and that bureau has attempted to use the full value of it in proportioning these important items.

For instance, the feed heaters of the Delaware were, for lack of data, proportioned on the basis of so many indicated horse-power per square foot of heating surface, and the two heaters combined have a total heating surface of 2,100 square feet. In her sister ship, the Utah, the same degree of feed heating is obtained with heaters having a total surface of only 512 square feet.

In the search for economy, the Bureau of Steam Engineering has adhered strenuously to the use of feed heaters with auxiliary exhaust steam as the heating medium, using any excess of exhaust in the low-pressure turbines or the second receivers of triple expansion reciprocating engines. This utilization of the auxiliary exhaust has not been to the taste of the turbine manufacturers who prefer to use all of this steam in the turbines, depending for feed heat upon that derived from steam drains discharging into the feed tanks.

That the bureau's contention that greater economy of fuel is obtained by the utilization of the auxiliary exhaust in the feed heaters is correct is shown by the curves given on Plate 33. The boilers of the vessels from which these results were obtained were so similar that the efficiencies may be taken equal, and the comparison can then be made on an assumption of 100 per cent efficiency without much error. The fuel oil per knot is obtained from the heat units per knot absorbed by the boilers for the different speeds, and dividing these different heat unit values by an assumed British thermal unit value per pound of fuel. At 29 knots it will be seen that the vessel making full use of her feed heaters required only 84.2 per cent as much fuel as the vessel putting all the auxiliary exhaust into the turbines (closed exhaust); and only 92 per cent as much as the vessel using the feed heaters to a limited extent.

The same comparison is shown on Plate 34, where are also shown the shaft horse-power curves for two vessels of similar hull but one being fitted with two shafts and the other with three. Here at 29 knots, the three-shaft vessel, though having a poorer propulsive coefficient than the two-shaft one, only requires 90.4 per cent as much fuel per knot. The shaft horse-power of the two shaft vessel is only 98.44 per cent of that for the three-shaft one. Had they been equal the fuel for the three-shaft arrangement would have been still lower as compared with the other vessel.

The improvements in evaporators consist mainly in the adoption of double effect connecting and in throwing open the gates to other than the standard bureau design, although these are not the only changes from former practice. Evaporator feed heaters, using the vapor from the evaporators as a heating medium, have been fitted, and vapor pipes better designed for the amount they have to carry are installed.

Until the adoption of electric-driven blowers for battleships and other large vessels and of turbine-driven blowers for destroyers and small vessels, the successful outcome of any heavy forced-draft run was always endangered by the unreliability of the blowers. Since the adoption of these types of blowers this danger of breakdown has been almost entirely eliminated, and, so far as the destroyers are concerned, the blowers may be classed as one of the most, if not the most, reliable of the auxiliaries fitted.

OIL FUEL FOR DESTROYERS AND BATTLESHIPS.

In deciding to adopt oil fuel for use on battleships and destroyers, the Navy Department took into account the following advantages which would be gained by its adoption:—

1. Less fuel required for any given radius of action, consequently less percentage of displacement and less bunker capacity required for the fuel.
2. Increased boiler efficiencies.
3. Decreased fire-room force.
4. Less deterioration of boilers due to maintenance of more even temperatures.
5. Ability to maintain high powers for indefinite periods.
6. Less deterioration of ship's structure due to there being no water or ashes in the bilges.
7. Greater cleanliness.
8. Greater ease in replenishing fuel supply, both in port and at sea.
9. Less floor space required for the development of a given power.
10. Greater ease in control of steam supply.

In opposition to these undoubted advantages the following disadvantages exist:—

1. Fuel oil less widely distributed over the earth than coal.
2. Greater unit cost than coal.
3. Greater danger of fire than with coal.

The reply to the first disadvantage is that in time of war a fleet operating far from a base would depend upon fuel ships for replenishing her bunkers, and that oil can be carried in bulk as well as coal, and bases where stores of

oil can be kept on hand are as easily established as are bases for coal, and such oil bases would have, in case of danger of capture by an enemy, the additional advantage of being much more readily destroyed, together with their stores of fuel, than are coal bases.

The second disadvantage, that of excess cost over coal, is more than compensated for by the quoted advantages.

The third disadvantage, that of danger from fire, is very thoroughly guarded against by storing the oil in compartments remote from the boiler rooms, and situated well below the water-line of the vessel. In addition to these primary precautions, additional safeguards are provided which render the danger from fire fully as remote as the danger from magazine explosions.

Upon deciding on the adoption of oil as a fuel for the naval service, the Bureau of Steam Engineering examined carefully all the systems for burning oil that now exist and finally decided upon that of mechanical atomization of the oil as the one most suitable for naval use.

In this system, the oil is pumped through heaters to the burners within which it is given a whirling motion. The small central core of oil, discharging through the tip orifice with this whirling motion, the oil flies off and forms a cone of fine mist. This oil mist mixes thoroughly in the furnace with air which passes into the furnace through a cone register surrounding the burner, the register having adjustable openings and guide vanes so that the amount of air to each burner may be regulated and the direction of flow of this air be slightly oblique to the axis of the cone of oil.

The success of the system depends almost entirely upon the proper handling of the air. Improper air regulation will produce a series of rapid explosions of oil in the furnaces with consequent destruction of the brick linings of the furnaces. With proper handling, the oil burns almost noiselessly, and the amount of smoke produced can be held absolutely under control.

In the first battleships fitted with oil fuel, the oil was only fitted as an auxiliary fuel and was intended to be used as an aid in keeping up steam when the coal should be so low as to be remote from the fire-rooms and so require excessive trimming. The results obtained with this mixed system are not to be rated as good nor were good results expected, as the furnace volumes of coal-burning boilers are too small to permit efficient burning of oil. Furthermore, when burning the oil and coal in combination it is impossible to so regulate the air supply that each fuel will obtain the proper amount. This results in excessive production of smoke and no increase in steam production over coal alone.

To illustrate the value of oil when used as the sole fuel as compared with

coal, Plate 36 has been prepared. The two fuels were tried under the same boiler, the grates being removed after the coal trials and the fronts rearranged to accommodate the burners and air cones.

To compare the relative values from this plate, let a ratio of heating surface to grate surface of 40 to 1 be assumed and a rate combustion of 40 pounds of coal per square foot of grate be taken, the coal having a thermal value of 14,500 British thermal units per pound. This rate per square foot of grate gives one pound of coal per square foot of heating surface per hour and a supply to the furnace of 14,500 British thermal units per square foot of heating surface per hour.

From Plate 36, where this value of British thermal units per hour per unit of heating surface is supplied to the boiler in the form of coal, the consequent evaporation from and at 212°F. per square foot of heating surface will be 10.8 pounds of water. Should this same amount of British thermal units, 14,500, have been introduced into the furnace in the form of oil fuel, the resultant evaporation would have been 11.72 pounds of water.

One pound of oil, however, may be rated at a thermal value of 19,200 British thermal units, therefore the total evaporation per pound of oil would be $\frac{19200}{14500} \times 11.72 = 15.519$ pounds against 10.8 pounds per pound of coal, a ratio of 1.437 to 1, while, if the thermal values of the fuels be compared, the ratio is 1.324 to 1.

The difference between these ratios, in favor of actual evaporative results, is caused by the elimination of all grate losses and losses due to sooting up of heating surfaces when oil is used.

CONCLUSION.

With such a large field to cover as suggested by the title of this article, the limitations as to length of the article prohibit anything more than a brief discussion of each point considered, but it is hoped that what has been presented will assure the Society of Naval Architects and Marine Engineers that engineering progress in the naval service has not ceased, and that the Bureau of Steam Engineering, greatly assisted by its co-workers in the development of the Navy, that is, the other technical bureaus of the Navy Department and the engineers of the various shipbuilding yards engaged in naval work, is to-day at least as progressive and as free from ultra conservatism as it has ever been in its history.

DISCUSSION.

THE PRESIDENT:—We will now take up the proceedings where we left off before the recess, and discussion is now in order on Paper No. 3, "Engineering Progress in the U. S. Navy," by Captain C. W. Dyson, U. S. N.

MR. CHARLES G. CURTIS, *Member:*—I would like to make a few observations on this paper, which Captain Dyson has, it seems to me, prepared with his characteristic ability. I think we are all very much indebted to him for having taken the trouble to write a paper which contains so much valuable matter and embodies so much practical experience. What I have to say should be put properly and accurately, involving figures and conclusions which must be correctly stated. For this reason, I am going to take the liberty of reading what I have to say. It will only take a few moments. It is as follows:—

In view of the fact that every important nation except the United States is now building turbine battleships exclusively, and of the fact that the improvements of the last few years have been such as to cause the most responsible builders here and in foreign countries to put forward figures of low-power economy on a par with the results shown by our reciprocating battleship, the Delaware, the views expressed in Captain Dyson's paper just read are most interesting, and to me somewhat surprising.

With many of Captain Dyson's conclusions I heartily agree. I cannot, however, agree with his conclusion that the reciprocator is preferable to the turbine for the kind of battleship under consideration—a view which is opposed to those of the best naval engineers in other countries.

In giving my reasons for the opposite view, I wish simply to put on record the facts and figures, stated as correctly as I am able to give them, realizing that whatever I may say on the subject will probably be regarded as more or less prejudiced because of my connection with and interest in the matter. On this account I invite criticism, particularly from our Navy Department. On the other hand, Captain Dyson has been the originator and developer of the most important improvements that have been made in marine engines in recent years. These improvements, though not generally appreciated, are all the more striking because of the belief long existing that progress in the direction followed by Captain Dyson was not possible. Not only is Captain Dyson entitled to great credit for his important contributions to the art, but in view of his success it would not be unnatural if he should have a slight unconscious leaning toward the engine rather than the turbine.

In Captain Dyson's paper he compares the engine-battleship Delaware with the turbine-battleship North Dakota in regard to coal consumption, the former representing the type of engine which has been carried to a high state of develop-

ment with remarkable results by Captain Dyson himself, the latter representing a type of turbine which was new, and which had undergone practically no development at that time. When the North Dakota's turbines were designed—about six years ago—but little importance was attached to economy at low speeds. The builders were not asked to make any effort in this direction, and the turbines were designed simply to meet the actual guarantees called for by the Department. These and the results obtained on trial were as follows:—

WATER PER HORSE-POWER (INCLUDING SHAFT HORSE-POWER OF MAIN TURBINES AND INDICATED HORSE-POWER OF ENGINE-ROOM AUXILIARIES).

	Guarantees.	*Actual trial results.*
At full power	15.1 lbs.	13.48 lbs.
At 19 knots	16.1 lbs.	15.37 lbs.
At 12 knots	23.2 lbs.	22.88 lbs.

The turbines thus met the guarantees in all respects, and were duly accepted. The excellent results at low speed subsequently obtained by the Delaware which were largely due to the improvements introduced by Captain Dyson, were not then anticipated, at least so far as we knew.

I have no doubt that Captain Dyson used the North Dakota's results for comparison with the Delaware, because there is no other battleship equipped with this type of turbine in this country, and I have such faith in Captain Dyson's fairness that I feel sure he had no intention of making an unfair comparison. Nevertheless the comparison is, in my judgment, quite unfair, and should not be considered except in conjunction with the improvements that have been made since that time.

Last winter a battleship was awarded to the Fore River Company which will be equipped with a more highly developed form of Curtis turbine, designed to give much higher economy under all conditions, particularly at low speeds. I believe, therefore, it will be illuminating to analyze the probable performance of this new ship, called the Nevada. Instead, however, of comparing one ship directly with another, which is always unsatisfactory where the models and the speeds are different, I will make the comparison between the old North Dakota and an assumed or new North Dakota, exactly like the old ship except that it is to be equipped with turbines and screws like those which are going into the Nevada. Such an improved North Dakota will be better than the old ship; first, because the turbines will be more efficient, that is, they will require less steam to develop the necessary shaft horse-power; second, because the screws will be more efficient for the reason that they are larger and slower turning, that is, they will require less shaft horse-power to develop a given speed of ship.

Plate 42 shows the actual water-rate curve of the main turbines of the North Dakota at different speeds of ship obtained on the official trials (no auxiliaries being included). It also shows the expected water-rate curve of the improved

turbines for the new North Dakota under exactly like conditions except at lower revolutions. It also shows the per cent gain in efficiency of the new North Dakota's turbines.

Plate 43 shows the number of heat units necessary to furnish the steam used by the turbines of the North Dakota and the engines of the Delaware. These curves are obtained by taking the actual water required by the main engines alone and multiplying by the total heat in the steam taken between the hot-well temperatures and the initial temperatures. The auxiliaries in this comparison have been expressly excluded, because it so happened that in the case of the North Dakota the official trials were made with fewer auxiliaries than was the case with the Delaware. In order to make a fair comparison, therefore, it is necessary either to exclude the auxiliaries or to assume an equal auxiliary consumption in both cases. I have thought it simpler to exclude them.

The third curve on Plate 43 shows the heat units that would be required by the turbines of the new North Dakota operating under the same steam conditions as the old North Dakota. This curve is obtained by multiplying the product of the water-rates and the shaft horse-powers for the new North Dakota by the same heat values as in the North Dakota. That is, the curve for the new North Dakota is based on the same initial steam conditions and same hot-well temperatures as the curve for the North Dakota, and the improvement shown is due partly to the gain in turbine efficiency and partly to the gain in propeller efficiency. The improvement in propulsive efficiency has been assumed to be ten per cent at all speeds. At the bottom of Plate 43 is a curve showing the per cent excess heat units required by the Delaware over the new North Dakota.

It will be observed that the Delaware at 21 knots requires 18 per cent more heat units than the new North Dakota, at 18 knots 12 per cent more, at 16 knots 5 per cent more. Below 14 knots the consumptions are practically equal.

This means that the new North Dakota could either have her boilers cut down 15 per cent, or her turbines could develop 18 per cent more effective or push horse-power with a given amount of steam. Allowing for an auxiliary consumption equivalent to that of the Delaware, this increased horse-power would give the ship an increased speed of one-half knot. In practical working, however, the turbine, because of the fact that it can safely be forced much higher above its normal capacity than the engine, can utilize more steam and can therefore develop a great deal more horse-power. With such a steam-generating capacity as our battleships are now provided with, the turbine ship could be driven at least a knot and probably a knot and a half faster. In this connection, I draw attention to the "Scientific American" of November 16, which states that the British battle-cruiser Princess Royal in her recent trials showed a mean speed over the measured mile of 33 knots, and a speed of 32 knots on the eight-hour full-power trial. This is 4 knots above the designed speed. This ship has a displacement of 26,300 tons, about the same as that of our last battleship, but is somewhat longer, being 660 feet.

Whether these curves are trustworthy or not depends, of course, upon whether

the expected improvements in both propulsive efficiency and turbine efficiency will be realized. Regarding the first point, experience had with screw designs since those of the North Dakota were made shows that their design can be materially improved, even without changing the revolutions. The expected gain due to better design, combined with lower revolutions, has been arrived at after consultation with Captain Dyson and his assistant, and I believe that the figure assumed is regarded as quite conservative.

Concerning the expected gain in turbine efficiency, a fear has been expressed that sanguineness may have induced expectations that cannot be reached. In answer to this I will state the grounds on which the expected improvements are based.

First. In the old North Dakota turbines there are 28 moving rows of buckets. In the new turbines there will be 97 rows. Although the peripheral speed is somewhat less in the latter, the efficiency is certain, judging from previous experience with actual machines, to be much better.

Second. The methods of calculation employed in arriving at the figures are founded upon constants which have been used extensively in this country and Germany, and also in England and France, and which have been shown to be reliable by application to many different types of turbines. The correctness of these methods has been confirmed by an immense practical experience in these countries with both the Curtis and Parsons turbines, including marine types.

Third. The results shown by a cruiser having turbines very similar in character to those under consideration, but of less horse-power, which were tested with great thoroughness during the builders' trials of the vessel several years ago. At 14.2 per cent of full power (corresponding with 12 knots) and a peripheral speed of 73.5 feet per second, the expected water-rate in the case of the new North Dakota is 16 pounds. Under similar conditions, but at considerably lower peripheral speed, and with fewer rows of buckets, the cruiser turbines show a water-rate of 17.1 pounds. At the same peripheral speed, they would have shown a water-rate fully as low as 16 pounds. The results shown by these cruiser turbines would of themselves seem to warrant full confidence in obtaining the results expected.

Fourth. Within the last year a number of large battleships have been ordered by some of the most advanced nations to be equipped with Curtis turbines of a similar character. In England a large battleship cruiser of 85,000 horse-power has recently been ordered fitted with Curtis turbines quite similar in character, and involving figures of economy quite as low relative to the conditions as those now proposed. As already stated, responsible builders have for some time been offering designs with assurances of economy at low power for battleships similar to that now under discussion, practically on a par with the figures shown by the Delaware.

Fifth. With four-shaft arrangements still better economies can be obtained.

I do not mean, of course, to predict that the exact estimated figures will be obtained. Every experienced engineer knows that in a machine of this kind the

results may come out a few per cent one way or the other, but even if they should fall short of expectation by say 5 per cent at full power, or 10 per cent at low power, such a possibility can hardly justify discarding the decided advantages of the turbine due to its full-power efficiency and its greater overload capacity and reliability, nor can it justify, it seems to me, the discouragement and set-back in turbine development in this country which is bound to result if the next battleship is equipped with engines.

In my judgment, the best form of propelling machinery for the next United States battleship would be straight turbines either in a two, three, or four shaft form, combined with small cruising geared turbines, which would be used only at low power, and on long cruises where economy was important. When these were in use the steam would pass first through the geared turbine, and then through the main turbines. A very large gain in economy, at least 25 per cent, can be had in this way at speeds in the neighborhood of 10 or 12 knots. The horse-power to be transmitted by each gearing would probably not exceed seven or eight hundred, and the art of turbine gearing has already reached a stage where the practical success of such an arrangement in a battleship is reasonably well assured. In England over 100,000 horse-power of geared marine turbines are built or building, and in this country a considerable number of geared turbines are now in operation, driving electric generators, and a much larger number are building. If any objection should be found to the geared turbines in service, they could be dispensed with, and the ship would still be a better proposition, all things considered, than if she were equipped with a reciprocating engine.

Holding Power of the Propellers.—I entirely agree with Captain Dyson that in all previous turbine vessels the propellers used have been altogether too small, and the result has been that in adverse conditions of wind sea, or of ship's bottom, not only does the efficiency fall off materially at high power, but the slip of the screws becomes so great that their holding power is quite inadequate. In our last battleship, the Nevada, arrangements have been made to use propellers having a disk area about 18 per cent greater than those of either the North Dakota or the Utah. I would, however, strongly advise using still larger propellers turning at a still slower speed. This would involve some loss in turbine efficiency, but it would be almost entirely made up by a gain in propulsive efficiency, so that the net result would be but little inferior to the present arrangment. Probably the difference would not exceed 1 or 2 per cent at full power and 3 or 4 per cent at 10 knots. This would give a much better and more manageable ship under all conditions, not only in going ahead but in backing. On a ship like the Nevada, I should advise using propellers at least 40 per cent larger in disk area than those used on the North Dakota, and turning at not over 200 revolutions per minute for full power.

Backing Power.—The backing power, or, more properly speaking, the efficiency of the turbines when backing, has in the case of the Nevada been largely increased over that of the North Dakota, so that this ship will undoubtedly be an entirely different proposition in this regard. With a steam flow equal to that used at full

power ahead, and at 80 per cent of the full-speed revolutions, the backing horsepower of the Nevada will be about 55 per cent of that developed at full speed ahead. Since a great deal more steam can be passed through the turbines than is possible with the engine, this can be increased at least fifty per cent so that a backing power as high as 70 or 80 per cent can be obtained, for short periods—as long as the boilers can furnish the steam.

THE PRESIDENT:—The discussion is still open. Mr. Emmet!

MR. WILLIAM L. R. EMMET, *Member:*—In the discussion of methods of propulsion I want to take an annual opportunity of saying a word for the electrical method. In the last few months we have tested the generating unit for the collier Jupiter, which is being built at the Mare Island Yard, and we have obtained from that unit the exact result which I predicted on it, which was considerably better than what we guaranteed on the ship. During its construction, however, we learned some things about turbines, and I arrived at the opinion that we could get very much better results by certain changes. So we decided to rebuild the turbine, retaining the high-pressure portion of that which we already had, and putting on a new low-pressure end. This new machine was tested last week, and it has given the best economy of any engine ever produced for any service. With only 5,000 kilowatt output we produced 72 per cent efficiency with steam having 100 degrees of superheat. The water-rate of the Jupiter, with 190 pounds pressure, saturated steam, and 28.5 vacuum, will be 11.2, which I think is about 2.5 pounds better than the best reciprocating-engine drive under such conditions.

This machine, instead of having so many rows of blades, and other elaborations such as have been spoken of here by Mr. Curtis, has only ten rows of blades, and the length of its group of wheels is only about five feet, and their diameter is about the same. It is an extremely small thing, any part of which can be handled and got at, it is extremely simple, and its parts are large and rugged. In comparing methods of propulsion, all that I insist upon is that due attention should be paid to the characteristics incident to the best propeller speeds and also to the characteristics incident to the best turbine speed. This new turbine of the Jupiter is a high-speed machine, which runs at 2,000 revolutions per minute, and it is a very distinct advance in prime movers over anything ever produced before. The merit incident to the best propeller speed and also the merit incident to such a turbine should be carefully weighed as against the characteristics of other prime movers of different speeds and resultant propeller characteristics. With electrical propulsion we select the best propeller speed, and there is a great difference in economy due to the best selection, as we all know, and as has been shown on the floor of this meeting. The question is: How shall we get these best speeds, and what can we afford to sacrifice in order to obtain approximations to them? With certain types of turbines you can produce very good results if the speeds are not too extremely low, that is, with certain improvements of speed in the existing marine turbine you

can make it very much better, and the aim of Sir Charles Parsons and others who have worked intelligently on the problem of gearing turbines to ships' propellers has been in the direction of a moderate speed reduction, making possible a good turbine, and at the same time retaining a fairly good propeller speed. I have nothing to say against this. I have experimented successfully on gearing a good deal myself, and I think that it is a very hopeful thing, but until we can have big enough ratios of speed reduction, it is not justified as compared with electricity, because the electrical equipment is extremely simple, extremely light, and has a high efficiency, which is perfectly well known and which is absolutely unquestionable.

The efficiency of reduction in the apparatus on the Jupiter is 92 per cent, that is, there is 8 per cent loss in electrical apparatus. Now if you study the curves of propeller performance you will see that small concessions in the matter of propeller speed cannot be made without losing more than that. From such data as I have been able to obtain concerning gearing, I do not see how a ship like the Jupiter could be properly propelled, with proper propeller speed and turbine speed, unless you use double reduction, and double reduction is a complication. Therefore my plea for electrical propulsion is that it gives us the rate of speed we want, something we know about, and we do not have to look into the future at all for our data. I simply say that the propulsion of ships by the methods now used is absolutely not justified in the light of the performance the Jupiter's machinery has made, the means of speed reduction being thoroughly well known.

The electrical propulsion designs which I have made, and which have been published in papers which I have read, show certain equipments which the developments of recent times has enabled us to considerably simplify, so that the electrical part is simpler than it was when I wrote those papers. Such means have been in part devised in connection with the driving of locomotives where we need a very high torque in securing the necessary starting power. In running electric locomotives a method of designing alternating current motors has been developed which has a characteristic, by the use of induction in the rotor, making the rotor so that it will give a high torque only when out of synchronism with the generator and will give good efficiency when it is in synchronism. This gives us the quality which we need in ship propulsion. This rotor is so constructed that its windings present a high resistance to currents of high frequency and a very low resistance to currents of low frequency. When a motor of this type is at a speed nearly synchronous with the generator the effective resistance of rotor winding is low and the motor is virtually as efficient as a motor of the ordinary type designed for small full load slip. When the motor departs from the nearly synchronous condition, as in the act of reversing, the self-induction of the rotor winding causes the bulk of the current to change its path, and to act through channels of high resistance, so that a high torque is maintained, as would be the case if a considerable resistance were actually switched into the rotor circuit.

By that method we can use a motor without external resistance, and this constitutes a very great simplificaton, because there are no connections to be changed, and the ship can be operated by simply throwing switches without inter-

ruption of field circuits. If I were redesigning the Jupiter equipment, I would have it arranged to be handled exactly as a locomotive is handled, by moving a little controller, so that I could stop the ship, or start her, or reverse her, and do everything that is necessary to be done through electrically controlled switches, and the opening and closing of those switches would be the only thing that would have to be done in connection with the whole manipulation of the vessel.

Now while it may appear to many that all this talk about the electrical propulsion of vessels is a waste of time, I just want to say that there is a great deal of attention being devoted to this subject, and in spite of all contrary opinions that have been expressed there will be a great many electrically propelled ships pretty soon. The subject is being seriously considered by many large ship users abroad, and is being more and more thought of here. It is a thing which should be considered simply on its merits, but if those merits are carefully considered, I think they will be seen to be very great.

Mr. Ernest H. B. Anderson:—I wish to thank the previous speakers for their remarks about gearing, because all the successful applications of turbine gearing have been carried out by Sir Charles Parsons, and our experience with geared turbines has shown remarkable economy of steam consumption and great success has been achieved with two destroyers, two channel steamers and cargo boats. It may be of interest to you to know that there is upwards of 100,000 horsepower of Parsons geared turbine machinery built and under construction——

Mr. Walter M. McFarland:—Does the gentleman dispute absolutely the statement made in Captain Dyson's paper, that the gearing on the Neptune is running successfully?

No reply.

Mr. Anderson:—As regards a comparison between the trial results of the Florida and Utah, I do not agree with the author that the efficiency of the propellers in the former ship fell off greatly, due to adverse weather conditions. To illustrate my meaning, I have plotted the trial trip standardization curves of speed and revolutions for both these ships. The two curves are very much alike. This is shown on Plate 44.

As you probably know, trial trip conditions vary so greatly that I do not consider it anything out of the ordinary that the Florida required more revolutions for the same speed, even though the propellers of both these ships are of the same dimensions. My opinion is that this difference is largely due to the finish of the propeller blades, and it is quite possible that the blades of the Florida wheels are thicker than those of her sister ship.

In addition, the Florida made new speed records for United States battleships—on the standardization trial 21.952 knots against the Delaware's 21.44 knots. Further, on the four-hour full-speed trial the Florida made 22.08 knots against 21.86 knots for the Delaware, the Utah on final acceptance, 21.92 knots for four hours, driving against a heavy breeze.

Plate 31 shows curves of indicated horse-power and shaft horse-power on a basis of speed for the Delaware and three turbine ships. My view is that the shaft horse-power figures are practically valueless, due to the fact that torsion meters are so erratic. Also, various types of torsion meters have been tried by the Navy Department, which accounts largely for so great a variation in shaft horse-power data of turbine ships.

A more accurate method of comparison is arrived at by basing water consumptions of machinery on the effective horse-power results obtained with the models of vessels pulled in the experimental tank. This was our regular practice before the event of the torsion meter.

The curves on Plate 32 are based on total water consumption of machinery "as measured" during the builder's trial trips. I do not consider that the Delaware and the Utah can be compared accurately on an equal basis in this manner. The following list gives the total steam consumption of the auxiliary machinery as recorded during the trial trip results of three ships, and for the battleship Utah I have estimated the auxiliary steam consumption from the turbine steam pressures, as the water consumptions of the main engines and auxiliaries were not separately measured:—

WATER CONSUMPTION TRIALS. AUXILIARY MACHINERY DATA—POUNDS PER HOUR.

	4 hours full speed.	24 hours (19 knots).	24 hours (12 knots).
Delaware	40,557	30,512	23,457
North Dakota	26,512	43,791	25,240
Florida	67,352	56,382	41,843
Utah (estimated)	62,400	47,400	29,500
Wyoming	—	—	42,200*

*Approximate.

The figures given show greatly in favor of the Delaware.

I have tabulated the auxiliary steam consumption of the scout cruisers at three different speeds, which shows that the auxiliary steam consumption of a turbine-driven ship and a reciprocating-engine ship are about alike.

WATER CONSUMPTION TRIALS. AUXILIARY MACHINERY DATA—POUNDS PER HOUR.

	10 knots.	20 knots.	Full speed.
Chester	13,752	24,303	40,025
Birmingham	11,809	21,162	41,551
Salem	14,601	22,907	46,003

It is rather curious that the auxiliary steam consumption of the Delaware and the scout cruisers at full power are about alike, although the Delaware requires fifty per cent more indicated horse-power under this condition. I fully believe that the only way to arrive at a true comparison between the Delaware and the Parsons turbine-driven ships is to send them out together for runs at cruising speeds, on conditions similar to scout tests, or preferably burning oil fuel only.

As regards Curve D, this is hypothetical.

The total coal consumption figures actually recorded on the builders' acceptance trials are of interest.

COAL CONSUMPTION TRIALS.

	Knots.	Coal consumption tons per 24 hours.
Delaware	21.56	578
Utah	21.042	468
North Dakota	21.64 (3 hrs.)	583.20
Delaware	19.217	319.20
Utah	19.225	283
North Dakota	19.21	292.50
Delaware	12.04	111.80
Utah	12.018	118.75
North Dakota	12.04	106.20

I have plotted a curve (see Plate 45) of speed and total coal consumption in pounds per hour for the Delaware and Utah. At 21.0 knots speed for the Delaware and the corresponding speed of 20.82 knots for the Utah, the Delaware burned 1.14 times as much fuel as the Utah, but at 12 knots speed for the Delaware, corresponding to 12.17 knots speed for the Utah, the latter burned 1.12 times as much fuel as the former.

Dealing with the question of breakdowns, I have been under the impression that reciprocating-engine ships do go regularly to navy yards for repairs. Newspapers have reported within the last year that the Idaho, Mississippi, Nebraska, and Connecticut have required the services of a navy yard to make repairs to the propelling machinery.

As regards breakdowns of the machinery in turbine-driven ships, only two of these causes are applicable to the turbines of Parsons reaction type.

Blade Stripping.—Practically all troubles of this nature have occurred in cruising turbines, and my opinion is that they are largely due to making the blade tip clearances too fine. We have aimed for getting maximum economy, when it is

just as essential to have naval machinery free from any possible chance of machinery breakdown. Blading troubles with the main turbines are very rare. When they do occur it is usually after opening up the turbines for inspection. The men who do this overhaul work do not realize the absolute necessity for taking proper precautions to see that no foreign materials are left within the casings.

Rotor Corrosion simply means a question of personal supervision down in the engine-room, and if instructions are faithfully carried out this will not happen. In the turbines of a battleship, rotor corrosion means neglect; for the interior of every rotor can be thoroughly examined by removing manholes on the casings and internal examinations should be made periodically. There have been one or two bad cases of rotor corrosion in the Navy, which have been largely due to neglect. On the other hand, there are many turbine-driven ships in the Navy which have had absolutely no trouble in this respect.

As regards reliability, take the engines of the scout cruisers, and recall the full speed trials of these ships when they were practically new.

The Birmingham made 24 knots, but it was found advisable to shut down at the end of 12 hours, and this ship returned to the navy yard for repairs.

The Chester made 25.08 knots for 24 hours.

The Salem made 24.32 knots for 24 hours.

Dealing with the somewhat vexed question of comparative machinery weights and engine-room spaces, I have extended the author's list and carried the comparison on to the latest battleships now under construction. In each case, I have first of all given the designed figures, or the basis of all calculation. Note that the displacement of each class of ship has steadily increased.

The weights included above were as follows:—

	Delaware.	Utah and Florida.	Arkansas Wyoming.	Texas and and New York.	Oklahoma.
Designed displacement	20,000	21,825	26,000	27,000	27,500
Contract speed, knots	21.00	20.75	20.50	21.00	20.50
Type of engine	Reciprocating.	Parsons turbines.	Parsons turbines.	Reciprocating.	Reciprocating.
I. H. P. design	25,000	—	—	28,000	24,800
S. H. P. design	23,000	28,000	28,000	—	—
Engine-room length	44 ft.	60 ft.	60 ft.	60 ft.	60 ft.
Mean width	50.50 ft.	51 ft.	52.50 ft.	53.50 ft.	58 ft.
Total area in square feet	2,222	3,060	3,150	3,210	3,480
Shop weights, gross tons	654.50	659.01	648.23	—	—

Delaware.—Main engines and lagging; throttle valves and fittings; forced lubrication casings on engines, pipes and tanks; exhaust pipes to condensers; 2 condensers, each 11,788 square feet C. S.; all shafting; spring bearings and stern tube bushes.

Utah and Wyoming.—Turbines and lagging; turbine regulating valves and pipes, all valves and pipes between turbines; forced lubrication system tanks and coolers; exhaust bends to condensers; 2 condensers (Utah, 15,225 square feet C. S. each; Wyoming, 14,008 square feet C. S. each); propellers and nuts; air and circulating pumps; all shafting and spring bearings and stern tube bushes; propellers and nuts; air and circulating pumps; vacuum augmentors for Utah.

As regards the total weight of the engine-room fittings of the Delaware and Utah, I do not consider they should be compared on an equal basis, as this is unjust to the turbine-driven vessel. I have, however, taken the actual shop weights of the Delaware and Utah and confirm the latter from the Wyoming, a still larger vessel, on what I consider to be an equal basis, and my figures show that the weights are about equal in the three ships, if anything in favor of turbine machinery.

Note that the total cooling surface in the condensers of the Delaware appears to be small, and in this instance it is less than the regular practice of the Bureau of Steam Engineering.

I cannot reconcile the weight given for the Utah.

The machinery weights of the Oklahoma will be much greater than the Delaware, for the reason that there are four condensers, four sets of air pumps, four sets of circulating pumps, and much longer pipe connections, etc.

Again, the machinery spaces in the three scouts are alike, and the following list gives the total machinery weights of these ships, which shows clearly that the advantage lies with the Chester.

TOTAL WEIGHT OF MACHINERY, INCLUDING WATER.

	Type of engine.	Weight, tons.
Chester	Parsons turbines	801
Birmingham	Reciprocating engines	844
Salem	Curtis turbines	909

As regards the engine-room floor areas, it is of interest to note that the Delaware is not being repeated.

There is one special feature I want to draw attention to, in connection with a comparison between reciprocating engines and turbines, *i. e.*, lost water or make-up feed water.

This loss has never been checked on a battleship trial; in a reciprocating engine it amounts to a very large quantity at the higher speeds.

COAL CONSUMPTION TRIALS.

	Knots.	Coal consumption, tons, 24 hours.	Make-up feed water, tons per day.
Chester	10.03*	42.06	10.97
Birmingham	9.86*	32.14	10.10
Salem	9.90*	53.85	11.66
Chester	19.90†	162.90	17.51
Birmingham	19.83†	153.45	26.10
Salem	20.25†	202.03	16.80
Chester	25.08‡	429.40	27.00
Birmingham	24.00‡	375.72	120.00§
Salem	24.32‡	415.15	45.63

*Test, 96 hours. †Test, 98 hours. ‡Test, 24 hours. §Leak in receiver pipe.

This list gives the water losses in the scout cruisers on three trials:—

1. At low speeds, slightly in favor of reciprocating engine.

2. At one-half and full power the losses in reciprocating-engine very great over that of the turbine-driven ships.

I would refer you to "Jane's Fighting Ships," 1912 edition, for an article on "Progress of Warship Engineering," which compares two Italian battleships, the San Giorgio with reciprocating engines, the San Marco with Parsons turbines.

As regards the question of maneuvering, there are over 44 shaft turbine-driven battleships and battleship cruisers now being handled successfully and easily. I do not consider the backing tests made during the builder's trials any criterion. In every case we have been very cautious about stopping the engines, and there is no question but that this can be done in very much quicker time with absolute safety to the machinery. The astern turbines are designed to develop 55 per cent of full-ahead power with the same quantity of steam.

In the case of the destroyers, on the builder's trials of the vessels finished this year, the backing tests were carried out practically twice as quickly as they were originally, and it was a matter of special comment on the way the boats stopped, when put full speed astern, going 29½ knots ahead. This will apply in a similar way to battleships.

CONCLUSION.

As regards the choice between reciprocating engines and turbines for battleships, I do not consider that the Navy Department has ruled in favor of reciprocating engines, for in the two battleships recently awarded one is being fitted with reciprocating engines and the other with Curtis turbines.

Another point that should not be overlooked—give the engineers time to know and understand this new machinery. For instance, it is new to practically every man on your latest battleships, the Wyoming and the Arkansas, and I know none of them have been shipmates with turbines before.

As regards economy at cruising speeds, from all accounts the ships of the Atlantic fleet are now cruising at speeds varying from 14 to 16 knots regularly, and under such conditions I feel certain that the turbine ships will compare equally as well, if not better, than the reciprocating-engine ships.

Your latest battleships are now being equipped solely for burning oil fuel under the boilers, and to my mind the only possible solution in such a case is turbine machinery; this has been proved conclusively in the destroyers.

The question of economy at the low cruising speed of 10 knots will now have to give way to a much more important one, namely, economy at the higher speeds. With a four-shaft turbine installation it is possible to get at least 2 knots more out of the vessel, without any undue strain on the machinery. I do not believe such a condition is possible with reciprocating engines. Further, there is only a very remote possibility by which the turbine engines of a four-shaft turbine battleship can be put hors de combat.

As regards a combination of reciprocating engines and turbines in battleships, if this is again proposed, I would suggest that the turbines be placed on the outboard shaft, which would get over the difficulty the author refers to, regarding the efficiency of the turbine wheels. It may interest you to know that this arrangement of machinery has proved exceptionally economical on larger merchant ships of moderate speed. Some of these ships have three shafts and others have four shafts. I do not, however, consider it suitable for a battleship.

Many improvements have been made in Parsons turbine machinery both in respect to improving economy and, what is also of just as much importance, less liability to breakdown.

1. Blading is being made more rugged by fitting two binding strips to the longer blades in place of one.

2. Radial dummies will be fitted in low-power turbines of battleships, avoiding all adjustments.

3. Greater attention is being paid to fitting auxiliary exhaust nozzles where they will give the best results, but I should like to mention that these connections were fitted and used on the Chester.

Further, it should be borne in mind that the Parsons turbines of the four battleships now completed have machinery installations which were designed in 1908.

Two destroyers fitted with Parsons reaction turbines of the latest design are now being built at the Bath Iron Works, and these designs contain many improvements over the earlier type. The machinery arrangement is entirely novel for destroyers, and I feel confident in making the statement that these ships will be the most economical throughout the whole turbine world.

Dealing with the present destroyers, of which there are twenty of practically the same design in commission, I consider the speed results, obtained with these three-shaft vessels, remarkable. The machinery was designed to develop 12,000 shaft horse-power at a speed of 29.50 knots. Many of them are able to make and are being forced along at speeds varying from 32 to 33 knots, which means that the turbines are developing upwards of 18,000 shaft horse-power. In justice to the turbines I think this is a very unsatisfactory state of affairs. It simply means that the life of the whole machinery installation is being shortened. Further, there is always a grave danger of an accident, due to excessive steam pressures. If 33 knots are required, build vessels designed to do this. Builders' trials are an entirely different question; more men are usually on duty at one time and a greater watch can be kept on the turbine bearings.

Further, on a ship in commission, the displacement is usually greater than with a ship on a builder's trial trip. The remedy is simple, and it is a very easy matter to arrange conditions in the engine-room so that the engineers on watch cannot get more than 30½ knots out of these ships.

References.—Journal of American Society of Naval Engineers: U. S. S. Delaware, Vol. 21, No. 4; U. S. S. North Dakota, Vol. 22, No. 1; scout cruisers, Vol. 22, No. 3; U. S. S. Utah, Vol. 23, No. 3; U. S. S. Florida, Vol. 24, No. 2.

Mr. Charles F. Bailey, *Member:*—I was very much interested in the paper presented by Captain Dyson, and being an employee of the Newport News Shipbuilding & Dry Dock Company, you may possibly expect me to refer especially to the Delaware. I do refer especially to the Delaware in this particular, that three weeks before the bids for the proposed battleships Texas and New York were opened, we were at the office of the Bureau of Steam Engineering discussing with Admiral Cone the possibility of his considering a bid for a reciprocating-engine-propelled battleship. He asked us if we could do as well as we did with the Delaware. We informed him we could do better, and we are attempting to do that.

It seems to me that the revival of the use of the reciprocating engine in the Navy, with forced lubrication, is significant at this time, in view of the development which has taken place in the Diesel or internal-combustion engine. You know Diesel engines are using forced lubrication, and by this means the engineers are able to run them without giving the usual attention to lubrication which is common to reciprocating engines. By the adoption of Diesel engines, or internal-combustion engines, in conjunction with steam-propelled engines, it seems that a large economy can be effected at the lower powers. Many of you are probably aware that several European powers are now building high-powered naval vessels with engines of the internal-combustion type installed for cruising purposes, with steam turbines for full power. I admit it is not yet practicable to install the immense powers to which we are tending in the battleships and cruisers in reciprocating-engine units; the turbine is best adapted for such powers. If the vessel is fitted with oil-burning

boilers the Diesel engine may be installed for cruising purposes to use the same grade of fuel as is burned in the boilers. By this method the cruising radius of the battleships, cruisers or destroyers can probably be more than doubled. One remarkable advantage that is apparent in the Diesel engines is that the fuel per horse-power is nearly as low at small powers as it is at the higher powers.

We have not yet made attempts in this country to install Diesel engines for the main propelling machinery in ships of the destroyer type or cruisers or battleships, but such engines are being installed on our submarine boats. It is my opinion that we must soon turn our attention to using the internal-combustion type of engine, probably in conjunction with turbines, for our large-powered naval ships.

Mr. R. C. Monteagle, *Member:*—This paper, though brief, is an admirably clear presentation of engineering progress in the Navy, and in reading it one cannot escape the conclusion arrived at by the Bureau of Steam Engineering, viz., that of placing reciprocating engines in heavy vessels of comparatively moderate speed.

The supplanting of steam-driven reciprocating engines is not imminent, nor do I believe such will be the case until every means has been exhausted to increase the efficiency of reciprocating engines, reduce their weight, and the space which they occupy. The various means of increasing such efficiency have not been exhausted, and the direction which I believe to be the most important, in which improvements to reciprocating engines is to be found, has been neglected. I refer to the increase of steam pressures. By increasing steam pressure, we at once have (with correct engine and boiler design) increased economy, reduction of weight, and reduction of space occupied by machinery and fuel. The pressure mentioned, viz., 265 pounds gauge pressure, is much too low to effect the economies attainable.

Steam pressures have not kept step with progress in other directions. If they had, they would now be approaching 500 pounds absolute instead of 280 pounds absolute.

In 1899 six cruisers were built for the U. S. Navy. These were fitted with Babcock & Wilcox boilers whose pressures were 290 pounds absolute. That is now thirteen years ago.. Why has a halt been called on increased pressures? Is it because of difficulty in getting suitable piston packing or suitable metallic packing for the rods? Or is it because boilers in their present form cannot withstand these higher pressures? If so, these objections are trivial, for they can be obviated. Rise in temperature has been regarded by many as an argument against higher steam pressures. But when it is realized that there is only a difference of 56 degrees in temperature between 280 pounds and 500 pounds absolute, this objection is seen to be invalid.

Large compound reciprocating engines of the horizontal type, in stationary plants, are using 150 pounds pressure and 150 degrees superheat with perfect success, equal to a temperature of 511 degrees. The horizontal type of engine, it is needless to say, operates under more severe conditions than any possible design of vertical engine, marine or otherwise. A distinct gain in economy has been made

as ratios of expansion have increased, but to proceed further in this direction in marine practice, steam pressures must be increased, as the point of cut-off cannot be advanced.

Quadruple expansion or quintuple expansion engines will be relatively as superior in economy to triple expansion engines as triple expansion engines were found to be in advance of compound engines. Quadruple expansion engines of proper design have already demonstrated their great superiority in the matter of economy to triple expansion engines, as is well known. Knowledge in the art of manufacturing high grade materials has advanced steadily, and it has now reached a point where very much higher steam pressures may be carried with safety. There is absolutely no doubt that engines and boilers can be built to withstand any pressure desired up to 500 pounds absolute. This pressure when compared with Diesel engine practice is low, and Diesel engines undoubtedly are being operated successfully now, in so far as strains on parts are concerned.

Engines and boilers must be entirely redesigned to conform to such pressures, and in doing so it will incidentally be found that some of the forms already adopted in boilers have been very far from perfection. With a pressure of 465 pounds absolute at the engine, a superheat of 40 degrees might be carried on the seven vessels of the Navy fitted for 85 degrees superheat referred to.

I claim for relatively higher steam pressures these benefits:—

1. Greater economy in steam and therefore in fuel consumption per horsepower. With 465 pounds steam at the engine close to 15 per cent in steam consumption would be realized over present practice.
2. Decreased size of steam cylinders, steam pipes, feed pipes and boiler plant.
3. Reduction of weights in engine and boiler rooms.
4. Decrease in space required for machinery and fuel.
5. Decrease in fuel required for a given radius of action. As the total heat units required to be absorbed by the boilers are less for quadruple or quintuple expansion engines than for triple expansion engines, the machinery spaces and weights could be reduced accordingly.

Mr. Walter M. McFarland, *Vice-President:*—I have only a word to say, but not in the general discussion of the paper. I called the attention of one of the speakers to the fact that he has made a broad general assertion which flatly contradicted a statement in the paper, and I thereby gave him an opportunity to correct what I thought was an obvious slip on his part. He did not make that correction, so I must state the facts myself. The paper by Captain Dyson states distinctly that the gearing on the Neptune has been a decided success. In the proceedings of another society there was a paper by the chief engineer, Lieutenant Smith, descriptive of the whole ship, which went into great detail about the gearing. Lieutenant Smith said the same thing—that the gearing has been a decided success. I do not want to detract at all from the credit which is due to Sir Charles Parsons for what he has done. I know the Vespasian was actually operating at

sea before the Neptune was. I do know that the gearing on the Neptune was developed by Admiral Melville and Mr. Westinghouse, the two great men I had the honor of serving. I do not think that the gearing was put on the Vespasian before Admiral Melville and Mr. Westinghouse started their work and began to complete their experimental installation. The experimental tests were made on the biggest scale of anything I have heard of—instead of trying it out on a few hundred horse-power, the test was made using 7,000 horse-power, which would be appropriate for a large ship. As I remember the figures for the Vespasian, they were 700 horse-power. Admiral Melville and Mr. Westinghouse gave this experimental gear a working trial lasting forty hours, developing 7,000 horse-power, the gearing being tested most carefully with an accurately standardized dynamometer, in order to determine the efficiency, which was shown to be very high. Such a test would count, of course, very strongly, as we have learned to-day, because we have heard how well the machinery of the Jupiter has performed in the shops of the General Electric Company at the Schenectady test. In the same way this gearing performed in the shop test, before the machinery of the Neptune was put on board the ship. Likewise Mr. Curtis has shown you that the machinery of the Nevada has performed well in the estimates and design.

The Neptune has been in service some two years, and has had some heavy weather, and all that sort of thing, and as a result the chief engineer of the ship, the man on the ship, and his superiors at the Navy Department who get the facts direct all say the gearing has worked successfully. Hence I am surprised to hear a gentleman say that the only successful application of gearing has been made by Sir Charles Parsons. I felt that I could not refrain from putting this on the record, out of respect for those two great men, Mr. Westinghouse and Admiral Melville, whom it was my pleasure to serve for many years.

Mr. Anderson:—I think Mr McFarland is quite right. The gearing of the Neptune has worked exceptionally well, just the same as this paper says; at the same time, has the whole of the machinery installation worked well?

Mr. McFarland:—I understand it works satisfactorily—not with the economy——

Mr. Anderson:—That is the whole point——

Mr. McFarland:—Let me finish—you asked me a question. Let me answer it, and do not stop me before I get through. You want to know if it has worked satisfactorily. I understand it has, but not with the degree of economy that was expected by Mr. Westinghouse. They will put other turbines in that will give the full economy.

Mr. Anderson:—I am pleased to hear that. Is there not some question of changing the actual gearing?

Mr. McFarland:—There is no question of changing the gearing, which, as already stated, is giving entire satisfaction.

Mr. Edwin A. Stevens, Jr., *Member*:—Mr. Anderson, in his discussion, compares the Birmingham with the other scouts. I agree that for such ships as the scouts, cruisers, and destroyers, there is much to be said in favor of the turbine, especially for the latter.

We all know that the advantages of the reciprocating engine, compared with the turbine, fall off decidedly in short-stroke high-speed engines such as those that have been fitted in destroyers in the past. Due to a large percentage of clearance the economy is poor, and also due to the inertia of the moving parts the high-speed reciprocating engines do not give satisfaction. Where Captain Dyson in his paper speaks in favor of the reciprocating engine, it is for a different type, namely, battleship engines, where about 126 revolutions have been the highest obtained, as in the Delaware. The engines in the Birmingham were designed for 200 revolutions, although I believe the piston speed is about the same as the Delaware.

In comparing the engines of the Utah with those of the Delaware and the Wyoming, I might call attention to the fact that the Wyoming is about 25 per cent larger than the Delaware, and has considerably more horse-power, while the Utah is only about 10 per cent larger, and her engines were designed for about the same horse-power as the Delaware, although she (the Utah) developed considerably more speed. Mr. Anderson complains that the Utah and Delaware is not a fair comparison, and then takes a much larger ship, namely, the Wyoming. The advantage due to size, if anything, would lie decidedly with the latter, as we all know the larger the power we build an engine, the weight per horse-power decreases.

The room for the machinery of the scout is, as Mr. Anderson says, the same, but how about the Delaware and Utah? Captain Dyson points out differently there. Another thing, in both Mr. Curtis' and Mr. Anderson's remarks about increasing the economy of turbine, the question of increase of weights has been avoided. If the increase in economy that Mr. Curtis speaks of in the improved North Dakota is realized, what will be the increase in weight?

Mr. Anderson mentions the Connecticut, Idaho, Nebraska, and Mississippi as being laid up at navy yards with broken crank shafts and other troubles. I would like to call attention to the larger number of ships there are in the Navy fitted with reciprocating engines than those fitted with turbines. Taking the proportion of time that the reciprocating-engine ships have actually spent in the navy yard for repairs, and comparing that with the time that the turbine-engine ships have spent, I think that the reciprocating-engine ship will be found to show up to advantage. The North Dakota, for the major part of last summer, was in the navy yard, and the Chester spent all of one summer in the navy yard for repairs.

If any ship with a broken crank-shaft is kept in a yard for any considerable time for repairs, it would probably be waiting for a new forging, which should

always be kept on hand, especially where ships are designed in units of 5 and 6, like the New Jersey and Connecticut class; in fact, spare crank-shafts are carried by many of our battleships. On the other hand, with turbine machinery it is different; they would be kept in the yard for a considerable time, because the work could not proceed any faster.

In the case of the Paulding, trouble was experienced with the high-pressure cruising turbine and it was taken out, and I believe she is to-day running without that turbine.

The engine-room of a turbine ship is considerably hotter than that of a reciprocating-engine ship, and anyone who has had experience with a hot engine-room knows what that means. I speak from experience, because last summer I was in the engine-room of the gunboat Marietta, where the thermometer showed 140 degrees within about two feet of a forced draught ventilator. One can readily understand the effect and the disinclination to work such an engine-room has on the personnel of the engineer division.

If, as Mr. Anderson states, no record has been kept of the amount of make-up feed water, where does he get his figures in comparing the Delaware with the turbine ships? He also makes a remark which would lead us to believe that as we are going to oil burners in battleships we will ultimately have to go to turbines. Why should oil burners be used any more successfully in turbine ships than in those fitted with reciprocating engines?

Mr. Anderson also says that they get more speed out of the turbine than the reciprocating engine. This is largely due to what Captain Dyson says, that the turbine is designed with more excess power than the reciprocating engine. If the turbine can use every bit of steam that the boilers will supply, as Mr. Anderson says, why could not the reciprocating engines, made slightly larger than the ones put in the ships already built, do the same thing?

Mr. Anderson also talks about the detrimental effects of the high-pressure steam, and states that a lower pressure should be used. I would like to ask what effect this would have in the weights, especially on our torpedo-boat destroyers, where the question of weights is a prime factor. He also states that the rotor corrosion is a matter of carelessness, that the manholes are made so that they can be examined, but no mention is made about the length of time required to raise the casing and also the time required to replace it, should this be necessary in order to check corrosion or for any other purpose.

Naval Constructor Richard H. Robinson, *Member of Council:*—One of the speakers who favored the turbine used the argument for it that a greater speed can be secured. As I understand the paper of Captain Dyson, it is not intended to indicate that the Navy Department makes any advocacy of reciprocating engines, as distinguished from turbines, except possibly in a ship such as a battleship, which is, comparatively, a slow-speed ship. This last summer I studied a good deal on the subject of high-speed cruisers, and what they were for, as distinguished from

battleships and what they were for. As I understand the matter, a battleship operates in a squadron with other battleships, and if it should happen that two or three battleships in a squadron have a couple of knots of extra speed, they cannot use this to any advantage, as they cannot go off by themselves. In the case of the battle cruisers and destroyers, however, they do go on and operate by themselves and for that reason the advantage of having one or two, or any additional number of knots speed up your sleeve, would be a very important element, more so than it would be in the case of battleships.

I would join with the last speaker and ask Mr. Anderson about the subject of weights.

Mr. Anderson:—With regard to the question of machinery weights, the different items included in the total given for each ship, are as follows:—

Displacement:—Delaware, 20,000 tons; Utah, 21,825 tons; Wyoming, 26,000 tons.

Delaware, main engines and lagging, throttle valves and fittings, forced lubrication casings on engines, pipes and tanks, exhaust pipes to condensers, two condensers each 11,788 square feet C. S., all shafting, spring bearings and stern tube bushes, propellers and nuts, air and circulating pumps, 654.50 tons.

In the case of the Utah and Wyoming, as follows:—Turbines and lagging, turbine regulating valves and pipes, all valves and pipes between turbines, forced lubrication system, tanks and coolers, exhaust bends to condensers, two condensers, Utah, 15,225 square feet C. S. each and Wyoming 14,008 square feet C. S. each, all shafting and spring bearings and stern tube bushes, propellers and nuts, air and circulating pumps and including vacuum augmentors for Utah. Total for Utah 659.01 tons and for Wyoming 648.23 tons.

The author gives the following engine-room weights in wet tons:—Delaware, 773.26; North Dakota, 785.93; Utah, 919.80.

These weights iuclude all the engine-room fittings, but the Utah is not on a comparable basis with the Delaware and North Dakota, for the reason that there is additional machinery in the Utah which is not installed in the Delaware or North Dakota.

Naval Constructor Robinson:—I am unable to quote the exact figures, but I am in the fortunate or unfortunate position of having to float this stuff. (Laughter.) I know that in every single case when we get a weight for reciprocating engines and a weight for turbine engines for the same design, there is a difference. I cannot, offhand, say just what is the difference; possibly it may be that the basis of calculation is somewhat different, but when it comes to calculating the displacement of the ship, you have to put additional displacement in to float the difference, whatever it may be due to. Similarly, it is often the case that I have to make assorted insides for these ships, one to take reciprocating machinery and one to take turbine machinery, and I am very much convinced, from the information we have,

that they do not go into the same space, as a matter of practical fact. It is of course true that we can and sometimes have put reciprocating engines in the larger space designed for turbines.

But, coming back to the subject of the increased horse-power that may be up your sleeve with the turbine-driven ship, my own opinion is, if it is there, as it appears to be, the proper thing to do would be to squeeze down the machinery that you use on the ship, so as to give you the horse-power that is necessary to give the speed you want, and make the ship smaller, or else put the difference to the credit of radius by increasing the fuel, or else add to the protection.

Mr. Anderson:—The engine-room floor spaces for the five classes of ships are as follows: Delaware, 2,222 square feet; Utah, 3,060 square feet; Wyoming, 3,150 square feet; Texas, 3,210 square feet; Oklahoma, 3,480 square feet.

You will see from this list that the engine-room spaces have steadily grown, and that the Delaware has not been repeated.

Mr. Luther D. Lovekin, *Member:*—There has been a great deal of talk about turbines and reciprocating engines and we have learned of their relative merits through the discussion by the various members of this society. Captain Dyson's remarks leave little to add to the great value of the reciprocating engine as applied to a battleship, as they are facts and not mere figures.

About two years ago I made a very comprehensive study of the excellent work presented by the late Dr. Thurston on the promise and potency of high pressure steam. Dr. Thurston predicted the use of steam of 500 pounds pressure and I wanted to see how such a pressure could be best utilized under existing conditions. I found it impossible to design a turbine for large powers that would handle this pressure with any degree of efficiency, in fact, where we use 300 pounds pressure the efficiency of the first stages is very poor. The reason for this is obvious, for as we all know, the turbine is an ideal "volume unit," but regardless of efficiency, we come to a point where casings of large turbines for the high-pressure units have a limit on account of the material necessary to use, viz., cast-iron. It, therefore, seems as though we would come to a standstill unless we again revert to the old reciprocating engine, which is the best accepted "pressure unit" that we know of to-day.

With the reciprocating engine we would have no difficulty in designing cylinders for 500 pounds steam pressure and exhausting the steam from these cylinders at 250 to 300 pounds pressure into properly designed turbines, and a water rate of 9 pounds, or even less, would be within reason.

We all know that if we are to save coal with the steam-engine it must come from the high-pressure end of the heat scale, and I should not hesitate for a moment to design an outfit of reciprocating engines and turbines combined, using 400 pounds steam pressure at the reciprocating engine and exhausting at 200 pounds into turbines, where the expansion would be completed. In order to obtain the greatest

possible advantage, I would use all cylinders as high-pressure, single expansive units with central exhaust.

We know that the U. S. Navy is using 500 pounds steam pressure with 300 degrees superheat at the Annapolis Experimental Station, and there seems to be no difficulty in handling it. We also know that the high-pressure end of the heat scale is all that we now have left, so why not take a decided step in advance and attain the 500 pounds pressure prophesied? It is certainly both possible and practical. Why not adopt it and bring the economy of the steam-engine more nearly that of the much-talked-of "oil engine."

THE PRESIDENT:—The hour is getting late, and unless there is some one who desires very much to continue this discussion, I will ask Admiral Cone to close it.

MR. W. H. HOWELL, *Member:*—What pressures are used on the forced lubrication spoken of in the paper?

ADMIRAL CONE:—About 15 pounds.

Mr. President, I assure you it is my earnest desire to close this discussion as soon as possible. I will take but a very few minutes. I feel that I will have to answer a few questions brought up here. Mr. Curtis mentioned the comparison of the North Dakota and the Delaware as being rather unfair. He is right about that; it is. I mean to say by that, that the North Dakota is of a design we know can be improved upon at the present time, and I know that Captain Dyson did not mean to take exception to the Curtis design, based on that ground. The increase in efficiency of the Nevada, which Mr. Curtis called the new North Dakota, at full speed, on paper is very gratifying, but we did not receive any proposition to reduce the boiler power when the ship was being laid down. Of course, that practically is the answer to the question.

The new propellers on the North Dakota are designed better for full speed, appreciably better, but not quite so good at the low power. Mr. Curtis takes us to task quite severely for not adopting a geared turbine auxiliary rig for cruising conditions, and while I think it has great promise, putting it into a plant costing $12,000,000 before it has been tried in service, is not, in my opinion, good engineering. We will probably try it on something not quite so expensive.

I notice in Mr. Curtis's remarks that we are not advancing, we are not trying out enough of these things, and I would like to state that within the last two or three years the Navy Department has had on its hands a number of new things. We have put into a collier a large power installation of geared turbines, have put into another collier an electric drive, we have put into some of our destroyers a reciprocating engine-turbine combination, and we have considered almost everything else that was brought to our attention. I do not see how we can encourage new things more than we have—what we have done almost covers the field.

To get down to Mr. Anderson's discussion, he makes a number of rather

positive statements of fact. He states that the turbine ship is not any more inefficient in a seaway, that the efficiency is not cut down by the seaway, while, on the other hand, we have a large number of reports from the fleet, made by officers on board the ships, which point to the contrary. It is possible that they may have a little better data on this point than has Mr. Anderson. All these points which Mr. Anderson has been figuring on here (referring to diagrams) I have not got through my head. Possibly I did not get it right, but most of it appears to be a question of water consumption per shaft horse-power or per effective horse-power, or per indicated horse-power. Captain Dyson has stated in his paper here, with which I think most of you will agree, that the basis we have it on now is fuel per knot, which answers all these complicated questions, and is a sound basis from which to start.

Mr. Anderson states that the Idaho, Mississippi, and Connecticut are frequently at the yard for repairs. They are. We have had quite a number of accidents recently in our shafting, and I will take the trouble to explain to you gentlemen that the casualties have been confined to the shafting. As distinctly stated in the paper, the ship with forced lubrication is free from trouble; it is true—Mr. Anderson to the contrary notwithstanding, because I have better data on that than has Mr. Anderson. Mr. Anderson mentions ships that are mostly old—the Idaho and Mississippi are ships that were laid down as 17-knot ships, and put in the fleet and required to steam with 19-knot ships, which we found was not successful from the shafting standpoint. It seems that the firemen are now able to get out of the boilers more power than the designers allowed for, taking data available at the time they were laid down, and because of liberal boiler power we have developed power with these engines far beyond what they were designed for. We are perfectly confident that we can eliminate shafting troubles in the cases mentioned.

As to the question of corrosion. Of course, it is hard for me to answer the broad statement that the corrosion is due to neglect. Any corrosion is probably due to neglect, but if you have a machine in the ship which you must turn over every fifteen minutes to keep it from corroding, it becomes a question of degree of neglect in practice. We are learning more all the time about stopping the corrosion. If it is such a simple matter as Mr. Anderson would lead us to believe I would like to have him inform me how to overcome it. It is a serious thing; some ships corrode and others do not, and we have not solved the corrosion difficulty, but we will probably do so in the end.

Now as to the weight of machinery. I would like to ask Mr. Anderson from where he got the weights he used. The weights that Captain Dyson gave to you are positive; they are the absolute weights. We weighed the parts with a scale, and I think some of the representatives of the builders here will agree with me that they paid quite a price for that excess weight.

Mr. Anderson:—The extra weights in the Utah over the other ships must include a large amount for magazine cooling, such as additional ice machines, with all their consequent pipings and fittings.

ADMIRAL CONE:—The two additional ice machines we have done away with.

MR. ANDERSON:—It is the biggest surprise to us to read Captain Dyson's paper and find that difference in the weight. We cannot explain it.

ADMIRAL CONE:—The difference in the size of piping made necessary by the different arrangement—would not that make up this great difference?

MR. ANDERSON:—The items already given in my paper under the heading of Delaware and Utah and Wyoming show what entered into the list. This list shows the amount of make-up feed water used in tons per day on the coal consumption trial of the scout cruisers at three different speeds. At 10 knots it was slightly in favor of the reciprocating engines, and at half power the reciprocating-engine losses were about 50 per cent greater than with the turbine ships.

ADMIRAL CONE:—I cannot understand why the loss of water should be greater with the reciprocating engine than with the turbine, for my observation with the turbine—and I have observed them a good deal on board ships—is that there is more leakage from turbine glands than from the reciprocating engine. It is one of the problems that we would like the turbine people to solve.

MR. ANDERSON:—The figures given in my discussion show the performance of the scouts on the 96-hour coal consumption test and also on the 98-hour coal consumption test.

ADMIRAL CONE:—Where did you get these figures from?

MR. ANDERSON:—I got them from the Journal of the American Society of Naval Engineers, volume 22, No. 3.

ADMIRAL CONE:—I cannot see where it is, but it may be. As to the maneuvering of ships, we will have to leave that point to the captains of the ships. I have any amount of data on that point, and I will ask you to speak to the captain of the Delaware or the captain of the Utah and get information on that subject.

Mr Anderson is correct in his statement that the Navy Department has not ruled in favor of reciprocating engines at all. We have taken in each case what we think is the best instrument at hand at the time to meet the conditions. The question of cruising at 14 knots and approaching a speed more favorable to the turbine is one that we designers in the Department cannot consider, as we are called on for definite cruising speed by the strategists of the Department, and we are called on to give a certain cruising radius, and the cruising speed of our ships at the present time is ten knots.

I note in Mr. Anderson's discussion that he calls us to account very severely

for over-running the destroyers and making more speed than the destroyers were designed for, going up as high as 33 knots; on the other hand he advocates very strongly the over-driving of our battleships, making a couple of extra knots on the battleships, but condemns in strong terms the over-driving of the destroyer. I think I would rather take chances on over-driving the destroyer than the battleship, and we are driving them hard, and we will probably keep at it for some time, until we see what we can get out of them.

In regard to the turbines, Mr. Anderson misunderstood the meaning of Captain Dyson's paper as I interpret it. I think there is no contention in this paper, as Mr. Robinson stated very clearly, for ships of high speed or large power, in favor of the reciprocating type of engine, and I am quite sure, from my dealings with Captain Dyson, that he did not mean that at all. The turbine scouts are much more reliable at full speed, and the reciprocating scout is considerably more economical at low speed, and as to the times that the ships have been in the navy yard, it is undoubtedly a fact that the turbine ships have been at the yard for repairs many more times than the reciprocating vessel, but that is neither here nor there, and should not operate against the turbine, as we must remember that these are the first two turbine vessels built by us, and we have improved on the design and management, and everything else connected with the turbine.

As to the question of space in the engine-rooms, that might be a little misleading. The Texas and New York have very large spaces in the engine-room, but they were originally laid out for turbine machinery, and probably we took an unfair advantage of Admiral Watt. An engineer likes a lot of room in the engine-room, and we are loath to give up a square inch of space, and when Mr. Bailey came along with the reciprocating engine it looked so good to us for the space we had in that it makes a good open engine-room, with space everywhere. I think Mr. Bailey will bear me out——

Mr. Bailey:—We did not object——

Admiral Cone:—I think Mr. Robinson and Admiral Watt are the two losers in that deal, and it is somewhat unfortunate that I have had to confess it.

I want to agree with Mr. Robinson in his statement about designing to the speed you expect to make. In our service we design a ship for 21 knots, and that is what our strategists want, and they make allowances for excess speed, etc., when they see fit. They want a ship that makes 21 knots, and in the case of the destroyer it is the same way. In other words when you lay down a ship for 29.5 knots, build it for that, and not have 4 or 5 knots up your sleeve. It is not good designing, and it is not good business.

As to the removal of the cruising turbines, I do not remember what was said, but they were removed as a matter of experiment so to speak, to see what effect it would have, and as far as we could judge it had no detrimental effect on the turbines.

If I may be permitted, I would like to say "Good afternoon." (Applause.)

Captain Dyson (Communicated):—Referring to the remarks of Mr. Curtis, while I would be very proud to be able to assume the responsibility for the design of reciprocating engines used in our modern battleships, I cannot do so without injustice to my predecessors who have been in charge of the Design Division of the Bureau of Steam Engineering, every one of whom has had his share in the development of this engine. I therefore can deny bias in favor of the reciprocating engine, and shall point out that, on the strength of the presentation of claims made in favor of the proposed installation of turbine machinery on the Nevada by the Fore River Company, I did not hesitate to express myself as being in favor of trying out the turbine machinery proposed for that vessel.

As to the comparison between the non-existent new North Dakota, and the Delaware, it appears to me that Mr. Curtis is indulging in prophecy based on paper work only.

Referring to Mr. Anderson's discussion, I shall first reassert my statement that the reduction gear on the Neptune has been perfectly satisfactory in operation. The propulsive coefficient obtained for this vessel basing it on shaft horse-power and effective horse-power, the shaft horse-power being measured forward of the thrust bearing instead of aft as is usually the case, was 62 per cent. If this measurement of power had been taken abaft the thrust bearing, the propulsive coefficient obtained would have been more nearly 65 per cent. The turbines fitted to drive the reduction gear were not entirely satisfactory and new turbines are to be fitted.

Mr. Anderson denies that the difference in horse-power between the Florida and Utah on preliminary acceptance trial was due to adverse condition of weather during the Florida's trial, and ascribes the difference to difference in propellers and to difference in torsion meters. In answer to this I would state that the Florida's propellers were built from the same plans as those of the Utah, practically the only difference being in the material used, the Florida's screws being of monel metal while those of the Utah were of manganese bronze. If an error is in the torsion meters and the Florida's shaft horse-power curve should be discarded and replaced by that of the Utah, the water consumption, based on shaft horse-power, of the Florida's turbines becomes at once excessive. He further denies the statement that excessive falling off in efficiency of propulsion, due to adverse conditions of wind and sea, the fouling of bottoms, and to increase of draught, is an inherent defect of turbine ships. In reply to this I would state that both the North Dakota and the Delaware have been standardized when drawing about one foot more than on their preliminary acceptance trials, and when out of dock, in the case of the Delaware fifty days, and in the case of the North Dakota seventy days, the two vessels having been together almost continuously during this period. The increase in power required for the Delaware, at 21 knots, due to fouling of bottom and this increased draught, amounted to 3 per cent, while for the North Dakota it amounted to 9 per cent; at 19 knots, for the Delaware 6 per cent, for the North Dakota 21 per cent; at 15 knots, for the Delaware 2 per cent, for the North Dakota 24 per cent.

Mr. Anderson makes the statement that a more accurate method of compari-

son is arrived at by basing water consumption of machinery on the effective horsepower results obtained with the models of vessels pulled in the experimental tank. This method is correct when we have similar types of machinery working under the same conditions as to steam pressures and temperatures, vacuum, and feed temperatures, but when these conditions are different we must reduce to British thermal units required to evaporate this water from similar conditions of feed temperatures, where it is possible to obtain such similar condition, exactly as it is done when we compare the efficiencies of boilers of different types by a comparison of rates of evaporation under similar conditions of fuel consumption, reducing the results to "from and at 212 degrees Fahrenheit." He carries this mistake into his comparison of the water consumptions for the auxiliaries, and makes no allowance whatever for the greater amount of heat required to evaporate a pound of water under the Delaware conditions over what was required under the Utah conditions, thus exaggerating the apparent difference between the two vessels, and attempting to cast discredit on the Delaware's performance by such exaggeration. I thoroughly agree with Mr. Anderson in his statement that the only way to arrive at a true comparison between the Delaware and the Parson turbine-driven ship is to send them out together for runs at cruising speeds, but modify it by stating that they should be under similar conditions as to displacement and length of time out of dock, and that the runs attempted should be for not less than 5,000 knots.

He speaks of curve D as being hypothetical. In this I do not agree with him. If it were not possible for the Delaware to carry the same feed temperatures as the Utah we might regard the case as being hypothetical, but where these feed temperatures can be obtained, and the condition of curve D be made actually to exist, it is perfectly fair to reduce the consumption of British thermal units to this curve.

Referring to the measurements of water consumption on the Delaware and to the guarantees for this vessel which were required of the contractors, I would state that the only guarantee was the speed guarantee. There was absolutely no guarantee on fuel consumption, nor on water consumption. The water consumptions were measured as accurately as it is possible to do such work on board ship. The reserve feed used was discharged into the measuring tanks and was weighed with the other water so that the weights of water given do include the reserve feed used.

Mr. Anderson's statement that the "loss water, or make up feed water, has never been checked on a battleship trial; in a reciprocating engine it amounts to a very large quantity at the higher speeds," is in the case of the Delaware absolutely incorrect. Furthermore, there being no penalty on water consumptions in the case of the Delaware, and as both the contractors and the Bureau were extremely desirous of obtaining as accurate data of water consumptions as possible, for use in future design work, there was no attempt whatever made by the contractors to jockey the results, and the water measurements were checked by both representatives of the contractors and by representatives of the Bureau of Steam Engineering.

Mr. Anderson intimates that the engine-room weights given for the Utah are not correct. In reply to this I would state that the weights which I quoted cover

the weights of main propelling engines, condensers, all auxiliary machinery in the engine-rooms, together with the weight of water included in pumps, piping, and condensers, and in addition the weights of the handling gear required for use in overhauling reciprocating engines in the case of the Delaware, and the turbine in the case of the Utah, the difference in weight due to the last item alone being very great. The weights given do not include anything outside of the engine rooms.

Mr. Anderson makes the statement, in speaking of the engine-room floor area, that it is of interest to note that the Delaware is not being repeated. In reply to this I would say that the floor area required in the later ships was fixed so as to permit the installation of turbine machinery should such installation appear desirable in the light of late developments, and advantage was taken of this increased area to idealize in laying down the arrangement of reciprocating engines and their auxiliaries. This latter type of machinery could have been accommodated in much less area had we so desired, but it would have been at a sacrifice of this idealization.

As to the relative maneuvering qualities of vessels driven by turbines and reciprocating engines, the turbine advocates do not hesitate to admit that it is a mistake to have reciprocating-engine vessels and turbine vessels in the same squadron, on account of the inferior maneuvering qualities of the turbine vessels.

Mr. Anderson further calls attention to the excess possible speed of the turbine vessel as compared with that of the reciprocating-engine vessel. In answer to this I would reply that if in designing the turbines the designers hewed as close to the line as do the designers of reciprocating engines this excess possible overload of the turbines would not exist, and therefore the excess possible speed would disappear. This over design of turbines for our battleships has resulted in making the ships over-engined, so that the only guards against excessive over drive of the boilers are the capacities of the feed pumps, feed lines and steam lines, the turbines being of such size that they will take all the steam that we can give them.

Finally, I do not wish it to be considered that this article was presented for the purpose of increasing antagonism to the use of turbines for propulsion of naval vessels. Such is not the case. I only desire to point out that the range of the turbine in which best results can be obtained is limited, as is also that of the reciprocating engine. Taking our present battleships of 21 knots speed, with the powers which we have used up to date, the advantage rests decidedly with the reciprocating engine, but should the power necessary to obtain this speed be increased to any great extent above that which is required for the New York, Texas, and the new vessel, the Pennsylvania, we would be driven almost necessarily to the turbine for our main propelling unit, and the probabilities are that when such becomes the case we will find the reduction gear has come into its own.

I wish to thank the Society of Naval Architects and Marine Engineers for the courtesy with which the article has been received.

The President:—You will agree with me that this paper which has been presented to us is a most interesting contribution to the records of our Society, and

on your behalf I will tender to Captain Dyson our sincere thanks for presenting the matters to us, and to Admiral Cone for presenting the paper to the meeting.

The program is only half over for the day, and the day is waning. Nevertheless, I am going to take the opportunity to interrupt the program. At the Council meeting yesterday afternoon the question of the provisions of the rider to Panama Canal Act came up for discussion; as this matter effects the interests of every shipbuilding and equipment concern in this country it was decided to have a committee appointed to prepare a resolution bearing on this matter with the intention of presenting this resolution to the President of the United States. Mr. Andrew Fletcher, the chairman of that committee, will make his report to you shortly.

We will now pass to the next paper, entitled "Marine Lighting Equipment of the Panama Canal," by Mr. James Pattison.

Mr. Pattison presented the paper.

MARINE LIGHTING EQUIPMENT OF THE PANAMA CANAL.

By James Pattison, Esq.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

In accordance with the plans of the eminent army engineers who are carrying the work to completion, the Panama Canal will be lighted throughout by automatic unattended lights, each having a distinctive characteristic. At the entrances and through Gatun Lake a double row of about sixty automatic acetylene lighted buoys will mark the channel. The channel will be further defined by powerful, rapid-flashing range-lights, one set at either end of each successive tangent, thus permitting vessels going in either direction to take their range over the bow. The center lines of each range are set apart sufficiently to enable the largest vessels to pass one another in safety. Through the Culebra cut, or wherever the proximity of the banks permits, beacons will be used instead of buoys (see Plate 46).

LIGHTED BUOYS.

A brief mention of the various types of buoys in general use to-day may be of interest in leading up to the description of the particular system adopted by the Isthmian Canal Commission.

It is generally conceded by lighthouse authorities that the lighted buoy is the greatest aid to navigation produced during recent years. It is inexpensive both in first cost and maintenance, and produces a highly efficient light of from six to fifteen miles visibility which will burn without attention and with absolute reliability for long periods, even up to a year or more if desired.

The use of oil as an illuminant for lighted buoys is now obsolete, and the electric light is yet quite impracticable for this purpose, so that to-day buoys are lighted with gas only—either oil-gas or acetylene. In the case of the oil-gas buoy, the nature of the illuminant renders its light weak and inefficient unless aided by an incandescent mantle, which, of course, is an added source of unreliability to be avoided. Oil-gas also loses a considerable amount of illuminating power by compression, owing to condensation of the heavy hydrocarbons.

Acetylene, a product of recent years, is, in this country, rapidly superseding oil-gas, its properties rendering it especially well adapted for buoy

lighting. Burned in a self-luminous burner without the use of a mantle the flame of acetylene gives an intensely concentrated white light, comparable only to sunlight. The illuminating power of pure acetylene is five times that of the richest oil-gas, and its efficiency remains unchanged by compression. For buoy lighting acetylene must be perfectly dry and of absolute purity. As generated from ordinary commercial carbide, it contains moisture and impurities which, if not removed, would rapidly clog the flashing mechanism or carbonize the burner. The earliest type of buoy using acetylene as an illuminant is the "carbide buoy," a Canadian invention, in which calcium carbide is stored in a receptacle having free access to the surrounding water. This buoy has the objection previously cited, namely, that the gas thus generated is not dry nor sufficiently purified for the proper and continuous functioning of the burner and flasher. This fault, combined with its inherent wastefulness, has gradually led to the abandonment of the carbide buoy in favor of the simpler and more efficient type, using dissolved acetylene, and now adopted for lighting the Panama Canal.

DESCRIPTION OF THE SYSTEM ADOPTED.

Beginning with its introduction to this country in 1908, this system (Dalén patents) has made such steady progress that to-day it is installed in over three hundred important light-stations of the United States and possessions.

To cite a few examples near home:—Ambrose Channel, the gateway of ocean commerce to New York, is marked by large buoys equipped with powerful, rapid-flashing lights visible at a range of over twelve nautical miles. The Delaware River channel to Philadelphia is lighted by beacons and range lights, from the light-vessel No. 44 off Cape May to the Horse-Shoe buoy and ranges at League Island.

Space will not permit of further enumerating the various channels, harbors, etc., lighted by this system, which will now be described in its application to the lighting of the Panama Canal.

THE BUOYS FOR THE PANAMA CANAL.

Plate 47 is a plan and elevation of the Panama buoy, in which *A* is the cylindrical body or chamber, 8 feet in diameter, made of $\frac{5}{16}$-inch steel plate with dished heads riveted on. Through the center of the body passes the tube *B*, to which is bolted the counterweight *C*. This tube is made in two pieces, as indicated at *D*, for convenience in ocean transportation. The pyramidal skeleton tower *E* is bolted to the cast steel foot-brackets *F*, and

carries the lantern *G* at a focal height of 15 feet. The draught of the buoy is 12 feet, and the total weight without anchor chain 10,500 pounds. Before painting and shipping the buoy is subjected to a hydrostatic test of 15 pounds per square inch.

The best materials and processes are employed for preserving the buoy from the severe corroding action of sea-water and sea-air. The entire inside of the buoy is first given one coat of bitumastic solution applied cold, and then one coat of bitumastic solution applied hot in accordance with the formulæ and processes of the American Bitumastic Enamels Co. The exterior is given one coat of boiled linseed applied hot and two successive coats of best quality red lead mixed with best quality of boiled linseed oil.

With reference to the gas supply and lighting apparatus, *H* represents the accumulators, of which there are four, filled with dissolved acetylene and inserted in the pockets *J*, which latter are furnished with hinged covers, *K*, for facilitating the removal and renewal of the accumulators. *G* is the lantern containing the pressure regulator or governor, as it is termed, and the flashing mechanism.

The high-pressure gas is led from the accumulators to a manifold, *L*, thence up the leg of the tower *E*, and through the shut-off-valve *M* to the governor. The gas piping is of special manufacture, made of solid drawn steel, 8 mm. outer diameter by 4 mm. inner diameter, with an outer protecting envelope of copper drawn thereon, which renders it completely rust-proof.

PORTABLE ACETYLENE.

The system of storing acetylene in portable accumulators is known as Dissolved Acetylene (D. A.), and is based upon the properties of acetone in combination with a suitable porous substance.

THE POROUS MASS—THE SAFETY DEVICE.

If a gas in a state liable to spontaneous dissociation or explosion is stored in a vessel whose diameter is less than that in which the explosive wave can be propagated, it is impossible to produce an explosion. Advantage has been taken of this fact in such a way that vessels are entirely filled with some very porous, solid matter, the minute crevices of which are almost of insensible magnitude. In a vessel prepared in this way it will be quite impossible to produce an explosion. This fact has been demonstrated beyond doubt by a variety of tests, and is practically recognized by the permission now granted in all countries to use compressed acetylene in vessels prepared according to this method.

The first condition with regard to the porous substance to be used is that it shall completely fill the vessel, leaving no space excepting the capillary canals formed by the substance itself. Other practical requirements are that it shall be perfectly free from action upon the acetylene (or the acetone—see below), that it shall possess a maximum amount of porosity, and that its consistency shall remain unaltered.

Of the porous substances hitherto used only one is known to have stood the test of years in regard to preserving its consistency unchanged. This porous mass possesses a porosity of 75 to 80 per cent.

Although a vessel thus filled with a porous mass only might well be used for directly compressed acetylene, yet it is not so employed for the simple reason that an additional means exists for vastly increasing its storing efficiency.

ACETONE—THE ACETYLENE STORER.

To Claude and Hess, two French chemists, is due the important discovery that acetone, a combustible organic liquid which boils at 56° C. (133° F.), possesses an extraordinary capacity for dissolving acetylene. At 15° C. (59° F.) a given quantity of acetone will absorb 25 times its own volume of acetylene at normal atmospheric pressure, and its solvent capacity is increased proportionately to the pressure, so that at a pressure of 12 atmospheres it can absorb 300 times its own volume of acetylene.

Important as this discovery was, it was not directly available for practical use. When absorbing acetylene, the liquid expands at the rate of about 4 per cent of its volume for each added atmosphere of pressure. Accordingly, a vessel intended for acetone saturated with acetylene under pressure can in practice never be entirely filled with liquid. During consumption, there would gradually be formed a space which would become filled with gaseous acetylene compressed above its limit of safety. This danger had to be avoided.

It was completely obviated by the invention of the porous substance already described.

Thus the illuminant, dissolved acetylene, was brought into existence.

THE GAS ACCUMULATOR.

The accumulators are prepared in accordance with the foregoing principles.

More specifically described, an accumulator is a steel cylinder tested to at least 50 atmospheres pressure (the type used on the Panama buoys, which

is the most common size, being tested to 75 atmospheres), and completely filled with the porous mass, a solid material possessing a porosity of 80 per cent. That is to say, although the cylinder is apparently filled quite full, only 20 per cent of the space is really occupied by the solid body, the remaining 80 per cent being available for holding the liquid. Half of this remaining space is occupied by acetone, which soaks into every pore of the porous substance; the other half, or 40 per cent of the original volume of the cylinder, is thus available for the expansion of the liquid. The cylinder is closed by a reliable valve, through which the gas is pumped into the accumulator, and through which it flows out again when required for service.

As the acetone charge is equal to 40 per cent of the original volume of the cylinder, and the solvent capacity of acetone is 25 times its own volume per atmosphere of pressure, the acetylene storing capacity of the accumulator is, accordingly, 10 times its own volume for each atmosphere. Therefore, at a pressure of 10 atmospheres an accumulator contains 100 times its own volume of acetylene; at 12 atmospheres 120 times, and so on; this being computed for a temperature of 15° C. (59° F.). The influence due to increase or decrease in temperature will be noted further on.

Accumulators are made in several standard sizes to suit different requirements. The three principal sizes used in this country for lighthouse work are designated A-25, A-50, AW-300, the index figure denoting the volume of the steel cylinder in liters, when empty (see Plate 48).

TABLE OF ACCUMULATORS.

Type.	Nominal volume.	Capacity.	Total weight charged.	Length including lap.	Outer diameter.
	cu. ft.			*ins.*	*ins.*
A-25.....	.88	90	120	49	$8\frac{1}{16}$
A-50.....	1.77	180	230	$69\frac{5}{8}$	$9\frac{1}{8}$
AW-300.....	10.60	1,100	1,410	$76\frac{1}{2}$	$22\frac{5}{8}$
A-600.....	21.20	2,200	2,450	84	$28\frac{3}{4}$

It will be observed from the above table that at 10 atmospheres pressure an accumulator stores about one cubic foot of acetylene per $1\frac{1}{4}$ pounds of its weight.

The greatest care must be taken at every step in the manufacture of these accumulators.

The high quality of the porous mass can only be obtained by a slow and laborious process which makes the substance light and porous, yet solid and enduring.

In order to obtain the highest solvent efficiency, only the purest acetone must be used.

Finally, the acetylene must be thoroughly purified and dried, to meet the severe requirements of lighthouse service.

INFLUENCE OF TEMPERATURE.

A notable feature of dissolved acetylene is that its usefulness is independent of the temperature. Acetone will not freeze; the gas accumulator can therefore be used in the coldest climates. For example, more than fifty dissolved acetylene lights have been installed in Alaska, and some of these installations operate the year round.

It should, however, be observed that changes of temperature, although in no way interfering with the usefulness of the gas accumulator, cause corresponding changes of pressure inside the accumulator. The solvent capacity of acetone varies according to the temperature in such a manner that while it amounts to 25 times its own volume at 59° F. (15° C.) it grows less at higher temperatures, so that at 122° F. (50° C.) it will be 50 per cent less, that is, only 12½ times its own volume, whereas it becomes greater at lower temperatures, so that at about −4° F. (−20° C.) it will be double, that is, 50 times its own volume. With a given quantity of gas in an accumulator, the change in the solvent capacity at various temperatures will reveal itself by corresponding variations in the pressure; when the temperature rises the pressure will gradually rise, so that at 122° F. it will be twice as much as at 59° F.; when the temperature falls the pressure will gradually decrease so that at about −4° F. it will only be half of what it was at 59° F.

These variations of the pressure will only slightly affect the gas quantity at disposal; however, every atmosphere's pressure indicated by the pressure gauge does not, at all degrees of temperature, represent the same quantity of gas at disposal; at 59° F. it represents 10 times the volume of the accumulator, at −4° F. it represents 20 times that volume, and so on. As the porous substance is not a very good conductor of heat, only a prolonged change in the temperature will materially affect the temperature in the interior of the accumulator.

UPKEEP OF ACCUMULATORS.

It will be readily understood that the accumulator is not a delicate thing. It will endure rough treatment or careless handling in transit. The strong steel cylinder cannot be easily dented. The valve is protected during transport by an iron cap. Inside, the iron is not affected either by acetone or by acetylene; outside, it only requires occasional painting to keep it from rusting. Neither will the porous mass cause trouble or require repair. As already stated, it has stood the test of time and, like the steel cylinder, it possesses practically unlimited durability.

On the other hand, the acetone filling from time to time requires small additions. Minute quantities of it escape with the gas, and this loss will be noticeable after the accumulator has been recharged with gas a number of times. The acetone will be replenished, when necessary, at the government gas-charging station which, it is understood, will be located at Balboa—the Pacific entrance of the canal.

These additions of acetone are made at an almost infinitesimal cost per accumulator.

In connection with the foregoing it should be stated that the admixture of acetone vapor with the acetylene by no means detracts from the light efficiency of the gas, but in reality is of considerable, practical value, as it causes the acetylene to burn more smoothly and keeps the burner cooler.

Replenishing of the acetone at intervals, together with occasional painting, are the only items of upkeep connected with the gas accumulators.

LIGHT APPARATUS.

From the foregoing it will be seen that acetylene is stored in the accumulators under varying degrees of moderately high pressure. At the burner, however, a constant low pressure is required; therefore the gas must be passed through a pressure regulator or governor, to reduce the high pressure to the required low constant pressure.

The governor, Plates 50–52, is the apparatus used for this purpose. Irrespective of the gas pressure in the accumulator, whether high or low, and of the gas consumption, whether large or small, the gas always issues from the governor at the constant low pressure suitable for the burner. All piping between the accumulator valves and the governor, through which the high-pressure gas passes, is of special manufacture five-sixteenths of an inch external diameter (see Plate 50).

A shut-off valve is conveniently located in the pipe line which runs up one leg of the lantern tower; this valve, as well as all other high-pressure valves used, are diaphragm-valves of an entirely new construction which precludes any possibility of gas leaking around the valve spindle.

The joints of the high-pressure piping are of special construction, exceptionally reliable and easily connected or disconnected.

In the base of the lantern where the high-pressure piping joins the governor, a special valve, 32, is employed (see Plate 49). This valve is provided with a connection to take the pressure gauge when reading the pressure in the accumulators. From this valve 32, the pipe 45 within the lantern base carries a filter F-500, which prevents any possibility of foreign matter entering the governor or flasher.

THE FLASHER.

An entirely new principle in flashers permits the production of as many as 55,000 separate and distinct flashes from one cubic foot of acetylene. Older types of apparatus could not produce more than 1,400 flashes from the same quantity of gas. The new flasher may be adjusted to give light periods of any desired length of time down to one-tenth of a second, or less, alternating with dark intervals of any desired length. Single, double or triple flashes, etc., can be produced with ease; in fact any light character obtainable in lighthouses equipped with the most modern lens arrangements can be produced by the new flasher.

For lighting the gas as it flows out of the burner during the light periods, a special pilot burner is used (see Plate 51). This continuously burning pilot flame consumes only one-seventy-fifth of a cubic foot of gas an hour, or about one-third of a cubic foot per day, as compared with 6 cubic feet per day in older acetylene flashers.

The *modus operandi* of the new flasher may be described as follows:—The gas issuing from the governor passes into the flasher *B*, through a valve which remains open during the whole dark interval (see sectional view, Plate 52). When a certain predetermined quantity of gas has flowed through the pipe into the flasher, so that the flexible leather diaphragm is at the top of its stroke, the inlet valve instantaneously closes, and simultaneously the outlet valve to the main burner opens, allowing the accumulated gas to pass through the pipe to the main burner where it is ignited by the constantly burning pilot flame. The pilot flame is fed through the by-pass direct from the governor.

The valve lever is magnetized so as to always maintain a tight joint

with the valve seats and to produce the desired instantaneous cut-off. The gas outlet now remains open until the total gas quantity has been consumed in the main burner, whereupon the outlet closes and the inlet opens, remaining open until a similar quantity of gas accumulates within the flasher, when the cycle of operations is again repeated. Thus the light and dark intervals alternate automatically and produce a uniform flashing light. The pressure of the gas flowing from the flasher to the burner does not vary during the entire light period, regardless of the duration of such period. In the older makes of flashers, the gas enters the burner at a low pressure which gradually rises to the maximum and falls again toward the end of the flash, thus wasting gas and making it difficult at long ranges to determine exactly the characteristic of the light.

LIGHT CHARACTERS.

The principle of the flashing light as a valuable navigation signal has been taken advantage of in the highest degree by designing the new flasher to consume the least possible amount of gas per flash and to make the dark intervals when no gas is being consumed as long as is consistent with efficiency. It is naturally of the utmost importance for the safety of navigation that the light character, *i. e.*, the ratio between light and eclipse, after having once been fixed must not vary in the slightest degree.

Nearly all lighthouse authorities agree that flashes of short duration followed by relatively short, dark periods are much more distinctive and efficient than long flashes, and this view is borne out by the fact that, of the thousand or more dissolved acetylene lights in operation throughout the world, the majority are adjusted for short flashes. Of the light characters adopted by the army engineers for the lights on the Panama Canal, the flashes do not in any instance exceed 2 seconds' duration, and the majority will be set to .3 of a second. The new flasher, although designed especially to suit short flashes, may easily be adjusted to give flashes of any desired length.

The flasher is easily and rapidly adjusted by means of accessible screws. Referring to Plate 50, the two caps, 23 and 25, serve to protect the adjusting screws of which 25 is for adjusting the length of the dark interval, and 23 for adjusting the length of the light period. Withal, the new flasher is exceedingly simple in principle of operation, and although sensitive it can withstand the most severe strains and jolts of the heaviest sea without variation.

Some typical examples of light characters as used in conjunction with

this system are shown on Plate 53. Fig. A illustrates a simple and widely used light character, .3-second light+2.7 seconds eclipse. In this example the light burns for only .1 of the total period (light and eclipse). Thus, if a ½-foot burner is used (which burning continuously consumes 12 cubic feet of gas every 24 hours), an accumulator A-50, of 180 cubic feet gas capacity, will last for $\frac{180}{12} \times 10 = 150$ days, from which, deducting for the pilot burner and allowing a large margin of safety, the light can be depended upon to run continuously for over 120 days or 4 months. The foregoing readily shows the enormous saving in gas and maintenance effected by those efficient short flashes.

As seen from Plate 49, the entire flashing mechanism is contained within the lantern.

THE BUOY LANTERN.

The Panama Canal buoys will all be equipped with sixth order lanterns. This method of dividing lighthouse lanterns into various orders is based upon the focal distance of the optic, that is, half the diameter of the lens at the focal plane as follows:—

Order.	Focal distance.	Diameter of lens.
	mm.	*mm.*
Hyper-radial	1,330	2,660
First order	920	1,840
Second order	700	1,400
Third order	500	1,000
Third order (small type)	375	750
Fourth order	250	500
Fifth order	187.5	375
Sixth order	150	300
Seventh order	100	200

With a 1-foot burner of 46 Hefner candle-power (the size adopted for the Panama buoys), the efficiency of the light through the lens will be 400 Hefner candle-power visible at a range of about 11½ nautical miles.

Such great candle-powers are obtainable on account of the high intrinsic brightness of the acetylene flame, which, being relatively small in size, permits of almost exact centering at the focus of the lens. Lenses consisting

of ground glass elements are now used in all modern lighthouse apparatus, the system employed for buoys being known as the Dioptric System, in which the light from the luminous source is collected and caused to travel along a horizontal plane by refraction (see Plate 54). The sixth order (300 mm.) Fresnel lenses for the Panama buoys are composed of nine separate elements, cemented together and held securely by a brass frame of helical bars.

To secure the maximum efficiency from the lens, the vertical bars of all standard buoy and beacon lanterns are equipped on their inner side with totally reflecting glass prisms, arranged so that the light which falls on any one prism is reflected out into the shadow caused by the adjacent bar (see Plate 55).

By a patented device, all of the light which emanates from the lens is affectively turned to account and uniformly spread throughout the complete horizontal plane, whereas in all other types of lanterns much of this light is obstructed by the bars and lost. The lantern consists of three principal parts, viz., the hood, the central belt, and the base (see Plate 49).

The hood, which is made of sheet copper, serves for ventilation, its construction rendering the lantern absolutely storm-proof, that is, making it impossible for wind or sea to extinguish the light.

The central belt is provided with storm glasses, through which the light shines. These glasses are held in place by vertical bars, equipped with reflecting prisms, as described above.

The base contains the flasher and governor, which are securely fastened with screws to the bottom plate.

Into this base is secured the lantern and pressure-gauge valve referred to on a previous page, and when required (as for beacons) a cock is fitted for use in connection with the sunvalve.

Although not employed on buoys, it may be of interest in concluding this paper to give a brief description of the sunvalve, the invention of the Swedish engineer, Gustaf Dalén.

THE SUNVALVE.

The sunvalve (Plate 56) controls the flow of gas to the burner so that the light will burn and gas be consumed only when actually required, that is, during darkness, thus effecting great fuel economy and increasing the service capacity of the accumulators. It is actuated entirely by light, and operates quite independently of temperature, so that it may be employed in any climate of the world. For example, many of the lights established by the United States Lighthouse Bureau in northern Alaska are equipped with sunvalve, also in the Hawaiian Islands and other tropical countries this

device is used with the greatest success. Its construction and operation are based on the well known physical law, that a body with a light absorbing surface attains a higher temperature and consequently expands more than a similar body with a light reflecting surface, when both are exposed to the same light. Plate 57 shows a vertical section through the sunvalve. The number 1 indicates a central copper rod, the surface of which is coated with lamp-black to give it the property of absorbing light to the greatest possible degree; 2 indicates a smaller rod, of which there are three arranged symmetrically around the central rod 1.

These three rods are also made of copper, but have surfaces of polished gold which causes them to reflect light to the greatest possible degree. The rods 19 pass loosely through plate 20, and serve only as a support for the dial plate 16. The rods 2 are held in position between the valve-body 22 and the plate 20 by means of the spring 21. The lower end of the central rod 1 bears on the valve lever 6 at a point between the fulcrum 23 and the valve seat 7.

When light is withdrawn from the apparatus, the rod 1 contracts and the valve 7 is opened by means of a spring 8, thus allowing the gas flowing into the valve chamber 22 through pipe 9 to pass out again through pipe 10 to the burner; but when light falls upon the apparatus it is absorbed by the blackened central rod 1, and transformed into heat which causes the rod to expand, and forces the valve lever 6 down upon the valve seat 7, thus shutting off the flow of gas to the burner. The rod 1 is arranged so that it can only expand downward.

The light which falls on the gold plated rods 2 is reflected out again without having any influence on them.

The upper end of the rod 1 bears on an adjusting screw 14, which is secured to the dial plate 16. By turning this screw up or down the position of the lever 6 can be adjusted to give the sunvalve any desired degree of sensitiveness. The position or adjustment of the screw is indicated on the dial plate by the pointer 15.

All the rods and the upper parts of the sunvalve are securely protected by the glass cylinder 18.

Within little more than a year the faith and enterprise of the American people will have been rewarded; through the wonderful skill and courage of their army engineers, the great connecting link between the two oceans will have been completed, the lights will have been established, and lighted; in daylight or in darkness, with equal security, the ships of the nations will pass through and a new chapter will have been written in the world's history.

DISCUSSION.

THE PRESIDENT:—Gentlemen, we will now take up for discussion the paper on "Marine Lighting Equipment of the Panama Canal," which has been presented by Mr. Pattison.

COMMODORE JACOB W. MILLER, *Vice-President:*—I have listened with much interest to the able paper which has been presented by Mr. Pattison, and as I am more or less interested in the lighting of ship channels would like to ask him a few questions, and obtain some information upon two or three points.

He says on the first page of his paper:—"It is generally conceded by lighthouse authorities that the lighted buoy is the greatest aid to navigation produced during recent years. It is inexpensive both in first cost and maintenance, and produces a highly efficient light of from six to fifteen miles visibility, which will burn without attention and with absolute reliability for long periods, even up to a year or more if desired."

I would like to take issue with him on the subject of the expense of lighted buoys now in use by the Light-house Department. Acetylene buoys are very expensive, costing from $2,000 to $4,000 each.

The claim that one of the advantages of the buoys is that they can be seen from six to fifteen miles is a disadvantage in the case of narrow waterways. The lighting of a canal prism should be in the nature of a series of stepping stones, from one light to the next with no overlapping rays of light. Strong, far-reaching illumination blinds and confuses pilots, and renders the navigation of narrow channels dangerous. My opinion is based on some experience on foreign canals and studies in this country. A few low-power lights at close distances, so that a ship can pass from one to the other without being confused with those beyond, are much better than any system of long-distance illumination, and I think this manner of lighting is being used through the narrow portions of the Panama Canal in the same way as in the Kiel and Manchester canals where the lights are only 300 feet apart, and that acetylene is only used in the Gatun Lake.

I trust, if there are any gentlemen here connected with electric lighting plants, that they will give us their experience of lighting narrow channels with low-power lights.

THE PRESIDENT:—Is there any other discussion on this paper? If not, will Mr. Pattison kindly close the discussion?

MR. PATTISON:—The same system of buoy lighting is used on the Ambrose Channel with the same kind of high candle-power lanterns. As far as the buoys used in the Panama Canal are concerned, the majority of them, as stated in my paper will be used throughout the Gatun Lake, which is quite a large body of water.

Through the Culebra cut electric lights will be used, as planned by the army engineers, also in the locks and the narrow portions of the canal, just as in ordinary canal lighting. In the Gatun Lake and at the sea entrances of the canal the system of buoys used will be the same as is used throughout the harbors and channels of the United States, that is, high candle-power acetylene lighted buoys, placed from half a mile to a mile apart, with spars or inferior buoys intervening.

COMMODORE MILLER:—I understood from this paper that it was devoted to acetylene lighting, and that was the only type of lights to be used on the Panama Canal.

MR. WALTER F. BEYER (Communicated):—Through the courtesy of Mr. James Macfarlane, one of your members, I had the privilege of reading the advance copy of a paper on "Marine Lighting Equipment of the Panama Canal," by Mr. James Pattison, to be read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.

Mr. Pattison's paper is interesting and illuminating in so far as it pertains to the gas buoys adopted for the Panama Canal, and descriptions of the various mechanical features which have made the use of compressed acetylene dissolved in acetone safe and reliable for lighthouse purposes; but his introductory remarks are misleading and give the impression that the illuminant for all the aids to navigation on the canal will be compressed acetylene dissolved in acetone.

Inasmuch as your Society has accepted Mr. Pattison's paper, and that it will receive considerable publicity, it appears to me that the approved project for lighting and buoying the canal should be placed before the members of your Society in the nature of a criticism, in order to avoid misapprehension on the part of all concerned.

On page 101 Mr. Pattison fails to qualify his opening paragraph by stating the illuminant to be used for the various lights, and on page 102 he fails to state that Ambrose Channel and Delaware River Channel are only partly lighted by the system of compressed acetylene dissolved in acetone.

On page 103 he fails to stipulate that the final coats of paint for the exterior of the buoys will be an anti-fouling paint for the salt water buoys and a special paint which will resist the action of the waters in Gatun Lake for the fresh water buoys.

A brief synopsis of the approved project follows.

The Panama Canal consists of 23 tangents. The scheme of illumination includes range lights to establish direction on all the longer tangents while side lights, with intermediate spar buoys one mile apart, mark the edge of the channel. The range lights are omitted in Culebra Cut where their use is hardly practicable, and on seven of the shorter tangents.

The project also includes a light and fog signal station at the end of the West Breakwater in Limon Bay, a light on the East Breakwater should it be built, and gas and nun buoys lighting and marking the channel to Mount Hope Dry Dock at Cristobal.

The proposed aids to navigation are numbered in the order in which they are used in passing from the sea on the Atlantic side through the canal to Miraflores Locks, and from the Pacific side in like manner to the same point. In order to simplify the numbering, however, the canal and its approaches are divided into natural districts as follows:—

Atlantic Section.—From Breakwater Light to foot of Gatun Locks.

Gatun Lake Section.—From foot of Gatun Locks to Bas Obispo.

Culebra Cut Section.—From Bas Obispo to Pedro Miguel.

Miraflores Lake Section.—From Pedro Miguel to Miraflores Locks.

Pacific Section.—From Pacific Ocean to Miraflores Locks.

All the ranges, except the Atlantic and Pacific entrances, will be so placed that ships after entering the canal will follow a sailing course 125 feet to starboard of the axis of the channel; thus two ships in passing will be 250 feet apart, center to center, and each will be running on a range ahead, thereby obviating the necessity of turning out when passing each other.

The entrance tangents, however, have the range on the center line and vessels will use the same ones whether entering or leaving the canal.

For marking the short tangents and for referencing the location of gas buoys, reinforced concrete targets will be used.

Range Towers.—The range towers are all of reinforced concrete and are of two general types. Those for the Atlantic and Pacific divisions, and for prominent places in the Gatun Lake Section, are of a more ornate description, while those for the Gatun Lake Section are very plain and inexpensive. The heights of the range towers vary from 28 feet to 105 feet from base to focal plane.

Beacons.—Where the shore line approaches close to the edge of the channel, the side lights are placed on reinforced concrete beacons.

These beacons are cast at the central plant in three parts—the body, the roof, and the post for the lantern. The foundations will be prepared for these and then a derrick barge will take them out and set them up in place, with the parts laid in mortar.

At the Pacific entrance the type of beacon is different from the general type because of the great range of tide which is twenty feet, and the low banks. It consists of a steel framework encased in concrete and supporting a reinforced concrete watch room and a lantern post. The foundation is a group of reinforced concrete piles capped with a concrete slab on which rests a small reinforced concrete caisson.

Buoys.—As stated above, the sides of the channel in deep water will have lighted buoys about every miles with intermediate spar buoys. Each buoy will consist of a cylindrical, floating, steel body surmounted by a steel framework which supports a light and lens at a height of 15 feet above water level. The body is 8 feet in diameter, made of $\frac{5}{16}$-inch steel plate with dished heads, to the bottom of which is attached a steel tube and counterweight. The draught of the buoy will be 12 feet, and it will be moored on its station by a heavy chain and a concrete sinker.

The corroding action of the salt water and the sea air in the tropics is such that extra precautions must be taken to protect the buoys, and therefore the entire inside of the buoy is given first one coat of bitumastic solution, applied cold, and second, one coat of enamel applied hot.

The exterior of the buoys which will be moored in salt water will be given one coat of boiled linseed oil applied hot, and two successive coats of the best quality red lead, after which they will be treated with an anti-fouling compound.

The entire bed of what will be Gatun Lake, when the water is allowed to rise to an elevation of 87 feet, is covered with a dense tropical growth which in the state of decomposition causes the water to scour all ordinary paints off any kind of metal. To overcome this chemical action the exterior of the buoys will first be painted with red lead and linseed oil, after which they will be painted with anti-corrosive paint.

Targets.—On the short ranges, and at certain points along the Lake channel, targets will be built to mark the center line of the canal or to reference the lighted buoys as the case may be. These targets will consist of a tripod 20 feet high made of steel angles encased in concrete, and the upper 8 feet of the tripod will be filled in from leg to leg with a plaster wall of metal lath. This furnishes a fairly uniform target from whatever angle viewed, and is permanent and inexpensive.

West Breakwater Light.—In the general scheme for lighting the canal, a harbor light and fog signal station is to be built at the outer end of the West Breakwater in Colon Harbor. An "L" turning inward will be made at the end of the breakwater and the tower built in it so that thorough protection from the waves will be obtained.

The natural bottom of the harbor at this point is mostly silt deposited by the heavy rains washing down the hillsides. On this silt a pile of rip-rap for the sub-foundation will be dumped, allowed to settle for some time, and levelled off by a diver at elevation minus 22 below mean tide.

The sub-foundation will consist of a reinforced concrete caisson 46 feet by 46 feet in plan by 36 feet high, divided into sixteen compartments by three transverse walls running each way.

The superstructure will be of reinforced concrete, and will contain an engine on the first floor, living quarters on the second floor, and a tower rising out of the center of the structure, surmounted by a lantern the focal plane of which will be 56 feet 4 inches above mean sea level.

In addition to a compressed air fog signal this station will also be equipped with a submarine bell. In this connection it may be stated that while there are practically no fogs at the Atlantic entrance to the canal, there are frequent and heavy rains, which with the aid of a fog signal will lessen the difficulty of entering the harbor.

Illuminants.—The illuminants will be acetylene gas and electricity, the latter being used in all towers and beacons convenient to a main line, and the former to all buoys and inaccessible lights. The candle-power of the range lights will vary from 2,500 to 15,000 or more, depending upon the length of the range. The most powerful lights, visible from 12 to 18 nautical miles, will be those marking the Atlantic and

Pacific entrances. The beacon and gas buoy lights will be about 400 candle-power.

To eliminate the possibility of confounding the lights with one another and with lights on shore, all range lights, beacons and buoys will have individual characteristics formed by flashes of light and dark intervals.

In the electric lighted towers the burner is so arranged that, when the lamp in place burns out, it drops out of focus and a reserve lamp drops into its place, thus minimizing the danger of a light being extinguished. This mechanism is operated by a shunt and series coil, the latter of which is thrown out when the light goes out, thus allowing the shunt coil to operate a lever and so replace the burnt-out globe with a new one.

Aids to Navigation.—The number and type of aids to navigation employed in the project for lighting and buoying the canal is as follows:—

1 harbor light (West Breakwater) lighted by incandescent oil vapor lamps or acetylene.

14 range towers, lighted by electricity.

18 range towers lighted by acetylene gas.

46 beacons lighted by electricity.

3 beacons lighted by acetylene gas.

59 gas buoys lighted by compressed acetylene dissolved in acetone.

100 spar buoys (unlighted).

2 gas buoys lighted by acetylene (channel to terminal docks and dry dock at Cristobal).

7 nun buoys unlighted (channel to terminal docks and dry dock at Cristobal).

At the present writing (November, 1912), contracts have been entered into only for 57 gas buoys lighted with compressed acetylene dissolved in acetone.

Mr. H. A. Gillis, *Associate* (Communicated):—Referring to Paper No. 4, "Marine Lighting Equipment of the Panama Canal."

This paper is one of the most interesting presented for some time on the subject of marine lighting and I think the thanks of the Society are due Mr. Pattison. However, I believe Mr. Pattison will be glad to have us criticize the paper and correct any mistakes apparent to us. We, therefore, would respectfully call attention to the following:—

On page 101, the question of reliability of mantles is spoken of, or rather the unreliability of the same. The average life of mantles on buoys, taken from over 2,000 buoys, is three months. In many cases, these mantles have run from 250 to 400 days.

I also note the question of loss of lighting power due to compression. The loss of candle-power due to compression is about 10 per cent.

As to the quality of lighting, the Pintsch mantle and the acetylene flame have almost exactly the same spectrum.

As to lighting power, it will be of interest to know the following:—

Acetylene (purified but not dissolved in acetone), 40 candles per foot.

Acetylene (dissolved in acetone, Presto-lite tank), 30 candles per foot.

Pintsch gas compressed to twelve atmospheres, flat flame regenerative lamp, 12 candles per foot.

Pintsch mantles, large mantles burning at 2 pounds pressure, 60 candles per foot.

Pintsch mantles, small mantles burning at 1 pound pressure (buoy type), 40 candles per foot.

Intensity per square inch of projection: acetylene, 32 candles per square inch; Pintsch mantles, 80 candles per square inch.

The spherical form of mantle is more advantageous when used with optical apparatus than a flat flame, as it approximates a point source and gives a smaller divergence to the beam; it has an even horizontal intensity in all directions, whereas a flat flame loses at least 20 per cent when set edgewise.

Actual photometric comparison of candle-power through 200 mm. lense, measured on 150-foot radius, shows:—Pintsch mantle, 140 candles; ½ foot-acetylene, 70 candles.

We note also that the writer states that the carbide type of buoy has been abandoned for the new type of dissolved acetylene. We do not know to just what country he refers, for the Canadian Government, as we understand it, uses nothing but carbide buoys. It is also true that the United States Government is now very much interested in the carbide buoy, and such a buoy, with a flashing light and actual gas consumption of 1½ feet per hour, ran for over 420 days in New York Bay. Another of this type, of different manufacture, with a fixed light, consuming 2 feet per hour, ran for nine months in Limon Bay, Panama. We believe it is also true that with proper purification generator acetylene gives higher efficiency than the dissolved type, the latter invariably carrying a small amount of acetone to the burner, which is borne out by the writer's statement on page 107, in "Upkeep of Accumulators."

In "Description of the System Adopted," on page 102, we note that the writer cites, amongst other examples, Ambrose Channel. This channel is lighted by a combination system of buoys, and the largest buoy and the furthest out to sea is the carbide buoy. This flashes five seconds light and five seconds dark and has a light source of about 75 candles in a 375-millimeter lantern. There are two entrance, two exit and two turning-point buoys of the compressed acetylene type flashing .4 second light and .8 second dark with a light source of 40 candles in 375-millimeter lanterns. There are also 12 Pintsch mantle buoys burning with a fixed light of 30 candles source in 200-millimeter lanterns. It might be interesting to note comparison of the gas in these buoys.

The gas in the compressed acetylene buoy, flashing .4 second light and .8 second dark, 40 candle-power, 300 feet per month, costs $4.50.

The Pintsch buoy, fixed light, 30 candle-power, 630 feet per month, costs $3.30 per month with a plain burner and $3.45 per month with mantle burner.

It is also to be noted that the dissolved acetylene buoy has a 375-millimeter lense against a 200-millimeter lense on the Pintsch buoy. In other words, if the Pintsch mantle of 30 candle-power were placed in the larger lantern, it would throw a beam stronger than the 40 candle-power acetylene flame, due to its higher intensity, or smaller area of projection. The range of the Pintsch mantle buoy referred to, with a 15-foot focal plane, runs from seven to ten miles.

We would also state that Gedney Channel has 12 Pintsch buoys flashing 15 seconds light and 5 seconds dark.

As to Delaware River, there are 10 Pintsch buoys and 1 compressed acetylene.

We note on page 103, under the heading "The Porous Mass—The Safety Device," the statement that it is impossible to produce an explosion. We know that this is the theory, but the facts, we believe, absolutely controvert this, as the records show that in the last few years a large number of explosions have actually occurred where gas has been put in receivers of this character. The record of such explosions is altogether too long to embody in these comments, but, considering the total number of flasks in the entire country charged with acetylene, the percentage is low and does not by any means discredit the use of this system of lighting.

We would also call your attention to the recent experiments at Stockholm, in which Engineer Dalen, the patentee of the system, was quite seriously injured and two of his assistants were also injured. We, therefore, think that the writer must necessarily modify his statement that it is impossible to produce an explosion.

Referring to the question of buoy construction and capacity, the Pintsch buoy, acting under its own gas, makes it possible to combine a large capacity, maximum strength and minimum weight. The minimum thickness of plates in this buoy is ½ inch, which makes the shell self-supporting and of sufficient strength to withstand the shock of collisions with passing vessels or floating ice. The float chambers of other type buoys must necessarily be made light, never over ⅜-inch for the largest buoys, and are only subjected to a test pressure of 15 pounds to safeguard against leaks.

The following is a comparison of weights and gas capacities of various type buoys:—

Generator buoy Willson No. 8½B	12,000 lbs	8,000 cubic feet.
Pintsch B–III	6,860 lbs	2,120 cubic feet.
A. G. A. (Panama Buoy)	10,500 lbs	720 cubic feet.

The buoy bodies in the case of the Willson and A. G. A. buoys are of about the same weight, 10,000 pounds, but where the Willson buoy holds 2,000 pounds of carbide, producing 8,000 cubic feet of gas, the A. G. A. buoy holds four 50-liter flasks, a total weight of 900 pounds, and a capacity of only 720 cubic feet of gas. Pintsch buoys are not painted on the inside, as the gas, being made from oil, itself acts as a preservative. Buoys fifteen to twenty years old still show the mill scale on the inside intact.

Referring to page 108, under "The Flasher," we do not see that there is any new principle emboided in this flasher, as it operates along exactly the same lines as the Pintsch chamber, with permanent magnets substituted for coil springs to hold the valves tight against their seats. As none of these flashers have been in service in this country, so far as we know, for over four years, and as the Pintsch chamber with coil springs has been in use over twenty years, it is hard to make a reliable comparison. We are informed, however, by the government lampists that when the dark period, as well as the light period, is very short, the constant shock of the armature striking the magnetized valve seats tends to demagnetize them and change the characteristic, which is to be expected, for it is a well-known fact that a permanent magnet becomes demagnetized if subjected to repeated hammer blows.

The necessarily small gas capacity of compressed acetylene buoys and beacons inspired of necessity the quick flash with relatively long, dark intervals, by which 90 per cent of the gas is claimed to be saved. We believe, however, that this type of characteristic does not receive general favor by navigators and those to whom aids in navigation are of most usee We believe the general preference to-day among mariners is for equal periods of light and dark.

The Panama type of buoy set with fixed light would have a life of less than a month, we believe, or, flashing equal periods, about seven weeks, whereas the Pintsch type of buoy under similar conditions would burn for three months with a fixed light and for six months with equal periods.

The Pintsch buoy is also adjustable within long ranges of light and dark and is supplied in single or multiple characteristic.

It might not be out of place to call attention to the type of lantern shown, which we think is weak. The vertical astregals have neither the strength nor rigidity of the helical bars with triangular storm panes. The light lost by the helix crossing the projected light beam is never over 10 per cent and at a short distance cannot be detected. The loss of light through absorption in the reflecting prisms equals that hidden by a helical astregal.

In conclusion, we believe that compressed acetylene as a method of lighting under certain conditions may be very advantageous. The Panama Canal Commission, we know, considered all the various systems of lighting before adopting this system.

Mr. Pattison (Communicated):—I wish to state that I have read the written discussions of my paper with much interest.

Mr. Beyer's communication covers very thoroughly the general nature of the various aids to navigation to be used throughout the canal.

As to the communication from Mr. Gillis I wish to take exception to some of the statements he makes. In the sixth paragraph of the first page, he presents figures showing comparison in light power of acetylene not dissolved in acetone, and acetylene dissolved in acetone.

Acetylene dissolved in acetone actually gives a better light than acetylene not

so treated. On the second page, second paragraph, he states that the Canadian Government uses nothing but carbide buoys; this is true enough, but it is also true that they are not giving satisfaction. They were purchased in large quantities by the Canadian Government shortly after they were invented, and they are now a white elephant in the government's hands. They are gradually being replaced by the superior type of buoys now used by the United States Government.

He also gives figures quoting an example of a carbide buoy which ran for over 420 days in New York Bay. Under favorable circumstances these buoys will run for such long periods, but such good conditions are very rare. Usually they cannot be depended upon with any degree of reliability. They are like the incandescent mantel in this respect. they may last successfully for a year, or fail after a day.

In regard to the third paragraph of the second page, he states that the Ambrose Channel is lighted by a combination system of buoys, the largest buoy being, he states, the carbide buoy. This is not true, as the carbide buoy he has in mind is established at the entrance to the Gedney Channel. Some years ago a carbide buoy was established at the entrance to the Ambrose Channel.

The dissolved acetylene buoys on the Ambrose Channel mark the principal turning points; buoys of different type are used along the straight runs. In passing I would state that if the incandescent mantel had proved reliable,then the Pintsch system of lighted buoys would be far and away the best in the world, and would have been used without a doubt on the Panama Canal, but they are now being gradually replaced by the more efficient and reliable dissolved acetylene buoys.

On the third page he refers to the explosibility of dissolved acetylene. I still assert and with absolute confidence that dissolved acetylene compressed in a cylinder, according to the system described in this paper, cannot be exploded except perhaps by placing the tank on a hot fire. The explosion he has in mind was produced by other systems of compressing acetylene, where the cylinders were not properly constructed.

In the second paragraph of the third page, he calls attention to the accident which occurred recently in Stockholm, in which engineer Dalen was badly injured. In this case the explosion was caused not by dissolved acetylene, but by another mixture of gases, which was being experimenteed with over a hot fire.

In the second and last paragraphs he speak of Willson's buoy which holds 2,000 pounds of carbide, producing 8,000 cubic feet of gas. It does produce this amount of gas and more, but where the buoy is exposed to rough weather, half the quantity is lost through over-generation into the sea. The carbide also disintegrates or falls through the grate into the sea.

In very calm water the carbide sludge hardens, and prevents the ingress of water, so that the lights go out.

As to the distinction between the flasher referred to in my article and the Pintsch flasher, it does embody a strict departure from the old type. In the new flasher mostly all springs are done away with and a magnetized lever is used instead, so that it is much more simple and reliable.

In conclusion, the fact that the Isthmian Canal Commission has adopted the dissolved acetylene system is preference to the older system, indicates that they consider the former to be superior. The same might be said in regard to its adoption throughout the United States, and the gradual abandonment of the older systems.

These I think are sufficient reasons to warrant the statements which I have made throughout my paper.

THE PRESIDENT:—The thanks of the Society will be extended to Mr. Pattison for his very illuminating paper.

RESOLUTION REGARDING THE PANAMA CANAL ACT.

THE PRESIDENT:—Mr. Fletcher, will you kindly read the report of the committee appointed to consider a part of the Panama Canal Act?

MR. ANDREW FLETCHER:—Mr. Chairman and gentlemen, we beg to submit the following report:—

STEVENSON TAYLOR, ESQ.,

President, Society of Naval Architects and Marine Engineers.

SIR: The Committee appointed by you to consider certain resolutions in relation to the Panama Canal Act beg to submit the following preamble and resolution:

Whereas, an Act to provide for the opening, maintenance, protection and operation of the Panama Canal, and the sanitation and government of the Canal Zone, approved August 24, 1912, contained the following provision:

"That all materials of foreign production which may be necessary for the construction and repair of vessels built in the United States and all such materials necessary for the building or repair of their machinery and all articles necessary for their outfit and equipment may be imported into the United States free of duty under such regulations as the Secretary of the Treasury may prescribe," and

Whereas, it has been brought to the attention of the Society of Naval Architects and Marine Engineers by certain members of its council recently in conference with United States Treasury Department officials charged with the interpretation and execution of the customs features of the foregoing law, that authoritative information as to the accepted interpretation of certain technical terms among technical experts in the shipbuilding art would be welcomed and given careful consideration, therefore be it

Resolved, That it is the opinion of this Socety, based on its familiarity with long-established usage of professional terms, that the provision of the Panama Canal Act, herein above quoted, admitting certain objects free of duty, does not include

structural materials finished and ready to be assembled in the ship; nor any finished machinery or finished parts of machinery to be permanently installed in the ship and necessary to the performance of her contemplated service, and be it further

Resolved, That in his letter of transmission the President of the Society be authorized to advise the government officials concerned that the Society would be glad to assist them in this matter of interpretation of technical phraseology or in any other way possible; also that a committee of technical experts, members of the Society, will be appointed with a view to conferring with the government officials having jurisdiction of the matters in question at such times and place as may be most convenient to the authorities in Washington.

Respectfully submitted.

(Signed) ANDREW FLETCHER, *Chairman.*
H. L. FERGUSON,
J. R. ANDREWS,
H. A. MAGOUN.

THE PRESIDENT:—Gentlemen, you have heard the report of the Committee. What is your pleasure?

A MEMBER:—I move that it be accepted.

THE PRESIDENT:—Is there any discussion?

Some discussion followed and the President then put the motion to vote, and the report of the Committee was unanimously adopted.

THE PRESIDENT:—In accordance with the instructions of the resolution, I will take pleasure in due course of transmitting this report, with the further suggestion to the Government as outlined.

The President subsequently filed with the Secretary the following telegram of transmission which accompanied the report of the Committee, and letter of acknowledgment:

29 WEST 39TH STREET,
NEW YORK, *November 21, 1912.*

TO THE PRESIDENT OF THE UNITED STATES.

At the annual meeting now being held in this city of the Society of Naval Architects and Marine Engineers, composed of those who are responsible for the design, construction and equipment of every American vessel of importance, the following preamble and resolutions were unanimously adopted, and we respectfully forward same to you, asking your consideration before further action is taken in the matter.

(Signed) STEVENSON TAYLOR,
President S. N. A. and M. E.,
29 West 39th St., New York City.

THE WHITE HOUSE,
WASHINGTON, D. C., *November 22, 1912.*

MY DEAR SIR:

Your telegram of the 21st instant has been received, brought to the attention of the President and, by his direction, referred to the Secretary of the Treasury.

Very truly yours,

CHARLES D. HILLES,
Secretary to the President.

MR. STEVENSON TAYLOR,
29 West 39th Street,
New York, N. Y.

As the final interpretation of the Act in question by the officials in Washington was in accordance with the above report, no further action by the Society of Naval Architects and Marine Engineers was deemed necessary.

EXTRACT FROM PANAMA CANAL ACT.

"That all materials of foreign production which may be necessary for the construction or repair of vessels built in the United States and all such materials necessary for the building or repair of their machinery and all articles necessary for their outfit and equipment may be imported into the United States free of duty under such regulations as the Secretary of the Treasury may prescribe."

Regulations are hereby prescribed as follows—Definitions:—

1. "Vessels."—The word "vessels" as used in this Act is defined to include all water craft of a character entitled to be documented under the laws of the United States or vessels of a similar character not required by law to be documented, such as revenue cutters, naval vessels, army transports, etc.

2. "Materials."—The word "materials" is defined as including any imported merchandise which is suitable for use in the construction or repair of a vessel or of its machinery to be incorporated therein after having undergone a process of manufacture subsequent to importation, or in its condition as imported, provided it has been purchased in the open market and was not constructed or fabricated upon a special order or after a special design. This will include raw materials, such as pig iron and lumber, to be worked up into the finished state in which they will enter into the hull or machinery, rough forgings and castings but not finished ones, nuts, screws, bolts, steel plates, ship's knees, flooring, and other things, which, though completed articles, are useful as parts in the construction of something else.

3. "Articles."—The word "articles" is defined as including only such things as are suitable for use in their condition as imported in the outfit and equipment of a vessel. However, articles will be considered as suitable for use in the condition in which imported, although they are to be fitted, polished, painted, or otherwise improved in condition or fixed in place subsequently.

4. "Outfit and Equipment."—The term "outfit and equipment" is defined as including portable articles necessary or appropriate for the navigation, operation, or maintenance of a vessel, and not permanently incorporated in its hull or machinery, and not constituting consumable supplies. The term includes, therefore, anchors, chains, cable, tackle, boats, repair parts, life saving apparatus, wireless telegraph apparatus (except the motor generator), nautical instruments, searchlights, signal lights, lamps, furniture, carpets, table linen, tableware, bedding, arms and munitions, and also articles to be used in renewal or replacement of articles of original outfit and equipment.

Materials and articles excluded from the benefits of this Act.

5. Machinery, including all the propelling mechanism, and also auxiliary machinery permanently incorporated in the hull of the vessel, such as pumps, steering gear, lighting plants, refrigerating plants, steam winches, hoisting engines, generators, motors, condensers, feed water heaters, evaporators, switchboards, etc.; provisions, wines, coal, medicines, and other similar consumable articles, and materials intended to be manufactured into articles of outfit or equipment, will not be admitted free of duty under this Act.

6. Neither materials for the construction or repair of vessels or of their machinery nor articles for outfit and equipment will be admitted free of duty when imported to be kept in stock for sale.

The President:—Paper No. 5 is now in order, entitled, "Notes on Life-Saving Appliances," by W. D. Forbes, Member of Council. I will ask the author to give us the meat of his paper as briefly as possible.

Mr. Forbes presented the paper.

NOTES ON LIFE-SAVING APPLIANCES.

By W. D. Forbes, Esq., Member of Council.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

The military members of the Society of Naval Architects and Marine Engineers will admit that the prerequisite of any weapon of war is certainty of action, that is, if any killing is to be done, it must be done with certainty. It would seem, if this be true, only fair that in providing means for preserving life, an equal amount of reliability of action should be demanded.

It requires a catastrophe to make people realize danger and to take steps to prevent its repetition, and it is somewhat strange to note that the death of 1,500 people at one time in one place shocks the world, yet the same number of deaths in an equal number of places at the same time awakens no comment whatever.

Enactment of new laws has followed the deliberations of the investigating committee appointed in this lamentable case, some wise and some otherwise. Yet the laws which hold come not from the deliberations of august bodies; none ever assembled could enact a law to make a man place his wife with her maid in a lifeboat and smilingly step back to death on a sinking ship, or bid a noble woman prefer death with her husband rather than live without him.

The greatest stress of both the American and English committees seems to have been laid on the matter of lifeboats, that enough of these should be provided for all on board, and in the United States, at least, the construction of lifeboats has been much improved. The most noticeable advance is in making the air tanks in metal boats independent of the shell plating, in other words, demanding a self-contained and detachable buoyancy medium. Many minor improvements have been ordered by the Rules of the Board of Supervising Inspectors, but to my mind the independent tank overshadows all other improvements.

In the matter of seams for the air tanks the question of brazing or riveting and soldering has been settled, allowing a folded seam, soldered, of course, in the place of a riveted or welded one. The original demand for gunwales of 26-foot boats and under was that they should be in one piece; this has been modified and a splice is now allowed. This is a most

reasonable modification as oak, the material named, is very hard to find in 30-foot lengths, free from knots and straight-grained, and in fact any other permissible wood of such length is rare and of course very expensive. The cost could be neglected, where human life is concerned, if any advantage were obtained, but the spliced gunwale is in every way as reliable as the whole-piece one.

The use of a steel keel seems to me, while more expensive, a very great gain over the use of a wooden one. It makes a stiff boat and this is of vast importance, as, under the present conditions of height of deck, lifeboats will have to be loaded before being swung overboard and, in rescue work, lifted from the water loaded, and strength to resist the strain of the load is better obtained by the use of steel. Steel keels have been used abroad long ago, and perhaps to some extent here, though I have noticed but few.

There does not seem to be any great debate as to the relative values of wooden or steel boats; both are allowed, yet the metal construction appears to be rather the favorite as it is lasting and always tight, while in my own experience the wooden boat is never so. I think the metal boat has the advantage of the celebrated one-horse shay in that it goes to pieces all at once and to an extent which demands immediate attention.

Life-rafts have been allowed for years as part of the ocean equipment for life-saving and no doubt in inland waters they would, under certain conditions, be of value, yet to my mind the only advantage, if it may be called one, in their use on the high seas would be that instead of perishing alone in your own individual lifebelt you would perish in the company of others on a raft. I cannot imagine any but the most hardy withstanding a night in winter on a life-raft, even in calm weather.

It was to be expected that after the Titanic disaster many suggestions would be offered for saving life at sea. One old idea, very much enlarged, is the old hen-coop system, that is, instead of a hen-coop floating off, as sea tales so often depict, the suggestion is to have an entire deckhouse float off. I have seen pictures of this system and one set of blue-prints of details, but even if the fact did not exist, that if a few beckets were not cast off or someone forgot to pull the releasing lever it would prove disastrous, perfect faith in automatic contrivances has not reached a point in the general make-up of mankind which would lead us to believe that an excited crowd would serenely await a ship dropping away under them, while seated on a detachable deckhouse.

It is clear from the investigations that lifeboats are the most important life-saving appliances. Very little if any stress has been laid on lifebelts, and it is therefore fair to suppose that these articles are satisfactory, to a

great extent, and there are several instances in the Titanic disaster which show their value.

It is very strange, indeed, that so little has been said as to the very important matter of launching the lifeboats. It must be at once conceded that no matter how many or how good the lifeboats on a ship may be, if they cannot be got overboard they are absolutely useless. It is no easy problem to lower away a boat, say 26 feet long, full of people, even in a calm sea and under no excitement, and taking into consideration the probable conditions of rough weather and a wild, frightened crowd, perhaps with the addition of a howling wind and darkness and cold, the operation presents serious difficulties.

Conditions make it hard to get real sailors in sufficient numbers to man the large number of lifeboats required on an ocean liner, and this adds to the difficulty of boat-launching; so the assertion at the opening of my paper holds true, and launching appliances certain in their action must be sought for. This is emphasized by the lack of skilled men, so none but the very simplest of mechanism should be considered. It may be truthfully said that if under excitement, or if training is lacking, should two things have to be done in sequence, the second one will be done first; the utmost we can expect is that one thing will be done when it is so arranged that nothing else can be done.

In order to get a boat into or out of the water, some form of overhanging arms must be provided. In years gone by these overhanging arms were built into the ship; later they became movable, and what is known now as the round-bar davit has held its place until it has become one of the most familiar ship fittings. In calm waters, such as the Hudson River or parts of Long Island Sound, this form of davit will answer certain requirements, particularly if the boats can be carried swung outboard, but when it comes to boats of large capacity in rough water, something better is imperative. Now what are the requirements of a good davit? Strength, simplicity of action, and perfect control.

It is fair to presume that the naval architect will provide the strength in any form adopted.

Simplicity is certainly found in the round-bar davit; it is a single moving piece and below that we cannot go, but I also demand simplicity of action. To swing out a boat with round-bar davits, one end has to be swung first; this has to be accomplished by heaving on the boat itself, or on guys, and after one end is swung out the davit has to be steadied by a guy and its lead to the davit head is not an advantageous one. True, there are round-bar davits that are turned by a worm and wheel and under some cir-

cumstances this is of great assistance, dispensing of course with the guying, but then comes the control. The round-bar davit has but one reach or overhang, and this is a serious disadvantage, but in this form it cannot be obviated, so beyond strength the round-bar davit does not meet the requirements of the high sea.

There have been several forms of self-acting davits presented, that is, they are so designed as to require only a small applied force to send them outboard. Those I have seen worked well enough in smooth water yet they, again, were either all inboard or all outboard and were hampered by too much mechanism into which ice, lines or other obstructions could easily get. Much ingenuity has been shown in this style of davit but none that I have seen seemed to fill any of the three requirements I have named, not even strength.

What may be called the fixed pin type of davit has been presented over and over again to the marine world. Plate 60 shows one of these. Here the form was used to meet conditions where deck room was very limited; this form has the advantage of being cheap. The screw which actuates the swinging arm is sometimes placed in a sleeve to protect it. The overhang of this davit is under control, which is one of the conditions I have named, but it is strong only in one direction, viz., across ship; but if a ship was pitching even moderately, should the lifeboat in swinging out strike the screw, great damage would result and most likely render the davit useless. The breadth of hinge, as it may be called, is relied on to give fore-and-aft strength, but it is evidently weak in this respect; unless made very much greater in in length than is shown in the figure, the construction would be far from rugged.

The fixed pin form just commented upon has for its counterpart the movable pin style, which is shown in Plate 61. Here a segment of a circle carries the arm and a screw controls its movement across ship. The advantage of this form of davit is most clearly shown by Table I and accompanying diagram; here the efforts on the screw are to be seen, as well as the effort required on a crank for swinging inboard and outboard. The weight of boat is taken as 3,500 pounds. In the pin davit 58 pounds' effort on the crank is required to swing the boat, while in the quadrant type but $8\frac{1}{2}$ pounds are needed; this is with an empty boat. When loaded (an additional weight of 7,500 pounds), the pin davit takes 160 pounds' effort as against $23\frac{1}{2}$ pounds' effort for the quadrant type. This figures out that the quadrant davit takes but 15 per cent of the power of the pin type, certainly an advantage. In swinging inboard, however, the advantage of the quadrant type is not so great as is shown by the table, since it takes 75 per cent of the effort required

for the pin davit, Table I giving the figures. The reason for this advantage is that as the quadrant rolls out, the fulcrum also moves out, while the working lever remains constant, the load lever being greatly reduced.

TABLE I.

	Comparative effort on crank 17 inches long.		
	Quadrant.	Pin.	Percentage.
	lbs.	*lbs.*	
Boat in inboard position, empty	$8\frac{1}{2}$	$56\frac{1}{2}$	Quadrant 15 per ct. of pin.
Boat in inboard position, loaded....	$23\frac{1}{2}$	156	
Boat in outboard position, empty...	75	101	Quadrant 75 per ct. of pin.
Boat in outboard position, loaded..	210	275	

Thrust on screws.		
	lbs.	*lbs.*
Boat going outboard, empty.....	415	2,750
Boat going outboard, loaded.....	1,150	7,600
Boat going inboard, empty.....	3,650	4,900
Boat going inboard, loaded.....	10,100	13,700

Form $P = \frac{Q \times r \times \tan(a+b)}{R} : c$

$a = \}$ $b = \}$ $\tan(a+b) = 0.25$

$c = 0.90$

$r = 1\frac{1}{4}''$

$R = 17''$

Q = thrust in screw.
P = power on crank.
a = screwpitch angle.
b = friction angle.
c = friction in bearings and thrust.
r = pitch radius.
R = crank radius.

The thrust on the screws of the two types of davits is interesting, as shown by the table referred to, and here again the quadrant type shows advantageously, but, as before noted, the inboard swing shows less difference. It must be remembered that the important thing to do is to swing the lifeboat outboard with ease, as when going outboard it would possibly mean a very great saving of life by its more rapid handling; but when boats are being swung inboard, the necessity for speed or ease of handling is by no means as important, as there would be less excitement and more time at disposal.

Both types of davits referred to have the advantage of allowing the overhang to be changed within the limits of the arms, and this advantage is great as it lessens the danger of the boat swinging away from the ship's hull and back against it. This danger, with a ship's deck 40 feet above the water, is too apparent to be commented upon, but it is interesting to note

that the striking blow of a loaded boat against a rolling vessel, allowing for the receding action of the ship, is calculated to be in the neighborhood of 40,000 foot-pounds. This blow of course depends for its value on the length of fall, the rolling period and weight; in the case cited it was 45 feet and the boat and its load were taken at somewhat over six tons (long).

It is an important point to be able to cast off the falls with ease after the lifeboat is water-borne, and many devices are on the market for this purpose; some are very good and others not so good. Such appliances demand that both ends can be released by one man at will and that each end may be attached instantaneously by the men stationed at bow and stern, and further that these operations can be done, beyond all shadow of doubt, in the dark.

A most common idea among those not versed in the handling of lifeboats is the supposed value of simultaneous lowering gear, that is, one which pays out each end of the falls evenly. This, of course, would be all right if the vessel was on an even keel, but if sinking at the bow or stern or pitching about this arrangement is a positive danger, as can be easily understood on a few moments' consideration.

While it is true that when lifeboats are to be taken aboard there is time available, it becomes a really serious matter to hoist a boat 40 or 50 feet, and while many hoists have been tried with more or less satisfactory results, there seems to be nothing on the market as yet which is all that could be wished. It is a matter well worth the attention of designers.

The demands of the new law as to lifeboats have forced upon marine people a difficult problem, as how and where to store the required lifeboats is a most serious matter to satisfactorily settle, and what are known as collapsible lifeboats—a style by no means new—are allowed by law to a certain extent. These never appealed to me, as under the usual conditions of abandoning ship, the necessary care to properly unfold and set up even a simple construction would probably result in failure.

A new form of lifeboat, which has a very great carrying capacity and may be nested to a certain extent, has lately been brought out and has met with the approval of the government officials. It is of the scow type but the bow and stern are raised high above the water, which gives it a great riding advantage in rough water. It is not what might be called a very rakish looking craft, but it has the inestimable advantage of being thoroughly practical, and the form is taken from the boats of the hardy watermen of the Scandinavian peninsula. Plates 63 and 64 give a good idea of the boat and method of stowing. Of course air tanks are provided, as is demanded in all metal boats, but these are built in. The spray boards require an intelligence about equal to that for lifting a refrigerator cover, or perhaps less because,

when once lifted, they stay in position. When folded down they form a firm platform to rest a second boat on.

The boat illustrated is 26 feet long with a beam of 8 feet 9 inches over fenders; carrying capacity, 50 persons. The design of this very practical boat could only come from one who had done more than read about life at sea, and it is due to one of our members, Capt. A. P. Lundin. A peculiar feature of this boat is the use of a very light wooden fender to add to its buoyancy; the wood used is known as Balsa wood and is about 25 per cent lighter than cork.

If we look calmly on the wrecking of the Titanic, are we not forced to the conclusion that the great lesson taught is prudence, and is it not possible that we can go so far in providing life-saving apparatus at sea that this lesson may be deliberately neglected? Yet while prudence is desirable and the perfecting of appliances might mitigate against it, we certainly should aim to obtain perfection.

My ideal of lifeboat equipment is a seaworthy boat of solid construction, davits which are worked from the ship's deck independently and with variable reach, a fall which is entirely controlled by a man in the boat, and a releasing device which can be made automatic or self-releasing when the boat is water-borne, or that can be detached at either end or both simultaneously. For returning the boat to the deck, I believe a power system should be fitted to at least two boats on each side, so that for rescue work the boat can be brought up with a run, to avoid being swamped in lifting. In rescue work, moreover, there is no reason why power cannot be applied as it would be available. The other boats carried would only be used if the ship was abandoned, and a quick power return on these is not so desirable because no master would hold boat drills in weather which would endanger lives and the boat; but for rescue work, it seems to me that a quick power hoist is imperative and it must be under control of a man in the boat.

To recapitulate, we can say there are three conditions which must be considered in handling lifeboats:—

1. *Drill*, when power is available. It must be admitted that under drill conditions there is no excitement, and calm weather would undoubtedly be selected for such work. The boats have to be got out and, of course, got back, but the operation is performed by men more or less used to life at sea, and it is safe to say that, with the appliances now at hand, drills can be satisfactorily carried on.

2. *Abandoning ship*, when power would probably not be available nor would it be required. The conditions are likely to be: an excited, frightened crowd, few of whom are used to the sea; probably a high wind and consider-

able sea; perhaps darkness and cold might be added. Yet with all these difficulties we can reasonably say that with the appliances which are now at hand, we are still able to cope with them, and lower away boats filled with passengers and get them away from the ship. Of course, at times the sea is smooth and conditions are most favorable, as in the case of the collision between the Republic and the Florida.

3. *Rescue work,* when power is available. Here the weather conditions are likely to be such as I have named for abandoning ship—as is natural to suppose—and we can readily imagine that some of the boats from the sinking ship are likely to reach the side of the rescuing vessel and have to be taken aboard as well as those which are launched from it. Now what is here demanded? A mechanical power, hand-power being out of the question on large ships; and the control of this power, I contend, should be in the hands of a man in the boat itself. Darkness, height of deck, wind and rain, make handling the boat to best advantage from the deck impossible. While all of us can make fair guesses of horizontal distances, few, if any, can do so where the matter of vertical height is in question, especially at sea, with a rising and falling medium below.

We would have power on board a rescuing vessel and I can see no reason why with, say, an electric drive, this power could not be controlled from the two boats on either side, which I deem necessary for this particular contingency, nor can I see why a properly designed friction hoist cannot be quickly and easily controlled from the boat. But in all cases, the first thing to do when a boat gets alongside is to get her quickly and securely hooked on to the falls. There are many devices now on the market for this purpose, but I would say that what is absolutely required for attaching the falls is a contrivance which requires but one motion and but one line of thought, when there is no necessity of regarding right or left hand but only that of doing one thing, and such contrivances are to be found on the market.

To go further into this matter of what is usually called releasing gear and consider the question of detaching a boat—if perfection is looked for—such gear must be so made that by the action of one person in the boat a release can be instantaneously effected at any time. I have never been able to thoroughly satisfy myself that what is known as "automatic releasing gear" is the most reliable and safest system to be employed, because the moment a boat becomes water-borne the releasing gear is detached, and unless the boat is held by a painter she is adrift; in abandoning ship perhaps this is just what is desired, yet it seems to me that it is better to have this releasing mechanism under the control of a man in charge of the boat, as there are

times when it is not advisable that a boat should be released the moment it is water-borne.

As to the means of supporting the boat while being lowered, or in other words, the davit, certainly during its across-ship motion control is absolutely necessary. I have seen round-bar davits swing out their boats with great rapidity and I have seen them come inboard again with equal rapidity—and with disastrous results. Any davit which is not locked absolutely in its entire travel seems to be almost criminal to use for deep-sea work. The quadrant davit, of which I have spoken, is absolutely fool-proof. But one thing can be done and one man can do it. It requires no previous experience as the operation consists in simply turning a crank, and even our good friends from the farms know how to do this from their experience with the grindstone for their scythes. The one objection is that the two davit-arms do not go out simultaneously, but one can with perfect safety be sent outboard ahead of the other and no concerted action is necessary. In fact, I have personally swung out a heavy lifeboat with a quadrant type of davit, swinging first one and then the other. In the matter of lowering, I cannot convince myself that it is not possible to have a system so simple that one man can control both ends of a boat with perfect safety, nor do I see that such mechanism need be very complicated, yet I am faced with the assertion of one of the great experts in lifesaving apparatus, Mr. Axel Welin of London, that a simple bollard is preferable on account of its absolute simplicity. Of course this is true, but is not this simplicity offset by the fact that to pay out a fall requires some nautical training, which may not always be available, and a properly designed lowering device might obviate this skill; yet it would take some mental effort, some experience and some coolness to handle the lowering device which I have suggested.

On October 22 and 23, the U. S. transport Kilpatrick was used by the Board of Lifesaving Appliances to test out the various designs of davits, releasing devices, lifeboats and rafts, etc. Probably no set of experiments ever made was more interesting or instructive. Unfortunately the weather was far too good to put to a severe test the apparatus which was fitted.

The tests began with swinging out the Lundin lifeboats which were nested on the upper deck, 33 feet from the water, Welin davits being used; these are of the quadrant type. The boats proved most seaworthy and thoroughly satisfactory in every way. A most interesting experiment was tried by suspending one of the boats about 6 feet above the water and passing a line to the tug Reno, which hauled the boat out about 6 feet and allowed it to swing back against the ship's side. In no way were the lifesaving quali-

ties of the boat impaired by this test. The circumstance of the test was that the Kilpatrick was listed 5 degrees which at the moment of test was added to by at least 3 degrees, making a total of 8 degrees, by a squall which had come up coupled with a driving rain and a wind of about 30 miles an hour; the ship was not rolling and the Lundin boat was on the weather side; the weight of the boat was 3,259 pounds.

Later two Lundin boats were made into a pontoon, shown in Plate 65. The pontoon was of the simplest construction, requiring no nailing, and only four bolts to hold it in place; this provided a platform of 575 square feet, floating 2 feet 3 inches from the surface of the water. When loaded with 91 persons, the value of such a platform for discharging stores or taking them in, landing troops with their horses, as a staging to bring boats up to, will be apparent to all military men.

This pontoon was towed by a launch with great ease and maneuvered readily by four men sculling.

A lifeboat of the Ingersoll type was thrown from the deck of the Kilpatrick into the water. She struck bow on, almost disappeared, righted herself and was self-bailed, clear of water in 14 seconds. The only damage done was a little denting of the bow when she went over the side. This boat was fitted with square holes for bailers, which passed directly through the deck, and also the plating, with no obstruction whatsoever. It came on to blow and this boat could not be made fast to the falls, so she was towed astern, and with these open scuppers the effect was very much that of a system of miniature geysers. I understand that later boats of this construction are provided with means to prevent this.

The very interesting, practical and convincing test, which showed the disadvantage of the pin-type davit, was as follows.

The Kilpatrick was listed 6 degrees, a pin-type davit fitted with a special handling device was tried, and the following time was noted:—

Weight of boat 2,250 pounds; 6 men in the boat; 7 men at the cranks. Under these conditions the boat could not be swung out. The men were taken out, and the 7 men heaving at the cranks were hardly able to get the boat outboard in 5 minutes 10 seconds. Later, with 7 men in the boat and an extra effort of the 7 men, the boat was got out in 8 minutes 2 seconds, but the men at the crank had to be "spelled."

Under the same condition of list the quadrant type of davit showed:—

Weight of boat 3,259 pounds; 11 men in the boat; one man at each crank; 1 minute and 40 seconds.

With a round-bar davit and the ship on an even keel the time required was as follows:—

Weight of boat 2,250 pounds; 18 men in the boat; 10 men at the davits; 5 minutes 15 seconds were required to swing it outboard.

A number of releasing gears were tried out, all with more or less success; in fact, it might be said that all of them performed the operations expected of them but only one of them seemed to me to meet the demands of absolute simplicity.

In concluding my paper I beg to say that the Board, which is composed of the following gentlemen, Col. C. B. Baker, Gen. George Uhler, G. A. Anthony, Naval Architect, Capt. James McKay, Capt. A. D. Lothrop, Capt. W. T. Oliver, is doing a great work, which will bear fruit, and the careful consideration and serious attention which these gentlemen gave to the various ideas presented show their determination to arrive at conclusions based entirely on mental deductions and not on personal preferences.

DISCUSSION.

The President:—Discussion on the paper "Notes on Life-Saving Appliances," by Mr. W. D. Forbes, is now in order.

Mr. Warren T. Berry, *Member:*—The first officer of one of the large Atlantic ships told me recently of having completely destroyed two all-wood boats by lowering them loaded to equal their full capacity, and suddenly checking the falls. There is evidently considerable room for improvement in the construction of lifeboats, and I think a steel keel is a step in the right direction.

Mr. Forbes refers to what he calls the hencoop system of life-saving, *i. e.*, a section of deckhouse so fitted that it can be released and floated off as the ship sinks. Of what value would this arrangement be in case of a fire serious enough to necessitate abandoning the ship?

Should the round-bar davit be damned by the faint praise that it has the advantage of simplicity only? When fitted with the proper worm and gear attachment it is adjustable as to outreach, as then it can be held either forward or aft of its extreme outboard position and so keep the lifeboat close alongside for loading or unloading. I have seen at boat drills many times a 26-foot lifeboat swung out, ready to lower, in considerably less than two minutes with such an arrangement.

The figures given comparing the effort required to operate pin-type and quadrant-type davits are not at all conclusive, possibly because the pin-type davit selected for comparison was not a good design. This also applies to the data given of time required to swing out boats with the pin-type davits.

I have recently tested a pin-type davit loaded with 2,500 pounds dead weight equalling a total load of 5,000 pounds on the two davits, which is slightly more than the load on the quadrant-type davits at the Kilpatrick test. No difficulty was experienced in swinging this load from the extreme inboard to the extreme outboard position in fifty seconds with two men. This davit was listed inboard 6 degrees corresponding with the Kilpatrick list. It can be seen in operation by any one interested.

Mr. Harold F. Norton, *Member:*—The paper just read has presented some very interesting information concerning life-saving appliances and has discussed various forms of boat davits, among others, one or two unsatisfactory forms of what is termed in the paper the "fixed-pin" type of mechanically operated davit. I should like to mention a satisfactory davit of this type, the sheath-screw davit (Plate 66).

These davits have already been fitted on eight or ten ships and by several of the principal yards, the Newport News Shipbuilding and Dry Dock Company, Maryland Steel Company, the New York Shipbuilding Company, and the Quintard Iron Works. A number of sets are being manufactured by the latter company for boats of the Fall River Line. These sets are particularly interesting in that they are fitted with a winch for lowering and hoisting the boat. By the courtesy of the Quintard Iron Works Company a plan of the arrangement is attached (Plate 67), and it is certainly a neat and compact arrangement of mechanically operated boat davit and winch. One of these davits is now set up at the Company's works, 742 East 12th Street.

The fixed pin-type davit shown in Plate 60 of the paper has a pin which is obviously too short and not properly supported in the fore-and-aft direction from the deck, nor is the support carried far enough up the davit arm, but the sheath-screw davit provides against all these objections by the long and substantial pin, with brackets extending well up the davit arm, and properly arranged deck connections. It is, of course, perfectly easy to design a pin connection entirely capable of accepting all of the strees transmitted to it from the davit arm, or which the deck connections are capable of accepting.

Another point commented upon is the liability of the screw-operated davit to injury of the screw by the fore-and-aft swing of the boat. In the sheath-screw davit the boat can never strike the screw but only the pipe sheath, and then only for a short part of the motion at the beginning when the boat is rising from the chocks, and when both sheath and screw are in positions to be least affected. Also the fore-and-aft swing of the boat is by no means so violent as might at first appear, which will occur to each member of the Society when he thinks of the necessarily slow longitudinal period of oscillation of a ship of any size, and then applies this to a pendulum of the length of the davit falls with the boat suspended above the deck, and acting within the comparatively limited space between the end of the boat and the davit itself. The quadrant davit illustrated in the paper appears to have no

particular advantage in this respect, since in its case the boat will strike against the cast-steel quadrant or the davit arm itself, the blow being transmitted directly to the screw and guide shaft. The blow may also occur when the guide sleeve is in the middle between the ends of the screw and guide shaft, a position in which they are least capable of sustaining it without injury. However, both constructions are so substantial that there is really no serious danger of injury from any blow likely to be received in this way.

The next point discussed is the comparative effort on the crank for the quadrant and fixed-pin types. It is a fairly simple proposition to figure static forces on an apparatus of this kind if the forces are in one plane, but when it comes to figuring frictional forces and making proper assumptions for coefficients of friction, the problem is much more difficult, and the expressions given in the paper appear quite too simple to be true. Probably they are not true of the turning effort required on the crank of a sheath-screw davit, for all the sets installed have been tested and found satisfactory, the empty boat or equivalent weight being readily swung out with one man on each crank, in a little over a minute's time. It is quite true that the quadrant-type is somewhat easier to start outboard than the fixed-pin type. on account of the more nearly downward direction of the boat from the start, but this is accomplished at the sacrifice of the feature that the boat shall be naturally lifted from, and over the chocks, and makes some special form of tumbling chocks always necessary with the quadrant type. Theoretically this type of davit ought almost to roll out of itself, if the ship is on an even keel, but the fact that some effort is required on the crank all of the way, is due to the introduction of numerous forces and frictional resistances, many of which are not mentioned in the paper or included in the formula. The forces are not in one plane, but on the contrary have several different planes and lines of action. By examining the construction of the quadrant davit illustrated in the paper, it will be noted that the davit arm is carried on an overhung pin cast in one piece with the sleeve embracing the guide shaft and the screw, the center line of the pin being about on the same level as the center line of the guide shaft, and the center line of the screw being some inches below and about vertically under the guide shaft. The pressure of the davit arm on the pin therefore exerts a considerable moment on the guide sleeve in one direction, which in turn being transmitted to the screw produces a considerable moment in another direction. None of the forces are in line with each other, and even the pressure transmitted by the davit to the pin is not a simple pressure, as there is quite a twisting moment introduced by the fore-and-aft overhang of the davit. All these forces must produce considerable frictional resistance, not to mention the friction of the rough rolling surface and the gear teeth where the quadrant meshes with the rack on the deck.

The forces on the screw-operated pin davit are somewhat simpler, being more nearly in line, but even in this case figures are practically worthless, and seem useless in the face of an actual trial with the loaded boat or an equivalent weight. The paper estimates that the quadrant type is also slightly easier to rig in, but it is very

doubtful whether this will be found to be the case in practice, and it is probable that on account of the various frictional resistances mentioned above, the quadrant type will be found considerably harder to rig in than a properly designed screw-operated fixed-pin type.

It is not explained in the paper that the pin-type davit mentioned on page 132 as being tested with very unsatisfactory results is an entirely unusual arrangement, wherein both davits are operated together through the meditation of a steel shaft connecting the two, this shaft being revolved by means of a worm quadrant, worm and spur gears, ending in a hand crank operating the entire arrangement. This apparatus resembles a quadrant davit about as much as it does the usual pin-type as previously discussed in the paper, and it is very misleading to mention this as "The very interesting, practical and convincing test, which showed the disadvantage of the pin-type davit," without explaining more in detail exactly what kind of a pin-type davit it is; but of course this feature probably did not occur to the author of the paper, as he doubtless intended no misrepresentation. The performance of the quadrant davit mentioned on the same page is about the same as should be expected of a well-designed screw-operated davit of the fixed-pin type, and is about what has been accomplished with the sheath-screw davit.

The principal advantage of the sheath-screw davit is that in stowage position the screw is completely housed and protected by the sheath and the sheath may be filled with grease for lubricating the screw.

In the quadrant type illustrated in the paper, the screw and guide shaft are exposed to the weather, protected only by a flat cover-strap an inch or so above the guide shaft, and although they are both of brass, it would seem that the action of air and sea-water must considerably increase the friction unless they are kept carefully cleaned and frequently greased. It also seems that a careless man might put a coat of paint on the guide shaft, the average painter being likely to consider it as proper a thing to paint as the cover-strap just above it. The quadrant, rolling in the groove with its gear teeth meshing with those in the deck rack, seems also to give such good opportunity for the accidental presence of foreign substances to make trouble, that it is remarkable trouble does not more often occur. Undue roughness or irregularity of either quadrant or deck casting will produce wedging action between the deck casting and guide shaft, or else throw all the weight of both boat and davit on the guide shaft. However, the large number of quadrant davits in successful operation shows that these conditions adjust themselves through the spring of the material, or in some such way, but it appears possible that they may make one davit of this type less easy to operate than another, and the same davit more or less easy to operated at different times, depending upon the kind of care it has had.

The sheath-screw davit is an attempt at still further simplicity and fool-proofness, by further obviating the necessity for care. But there is still something to be desired, as the pivoted thrust bearing on the deck frame is now exposed to

the weather. A further development in this davit which is now being attempted, is the production of a satisfactory oil and water-tight ball thrust bearing, so that this bearing may be kept full of oil and at all times protected and lubricated, just as the screw is protected and lubricated by the sheath.

Mr. J. Howland Gardner, *Member*:—I have listened with considerable interest to Mr. Forbes' notes on life-saving appliances. It would appear from this paper that the writer's experience has been limited mostly to experiments with the Welin-type davit, which is well designed and very efficient, and a few other types of davits of inferior design. I say inferior design, because there are davits of the various types mentioned that fulfil all of the requirements laid down in this paper. Among others might be mentioned the Norton davit. Mr. Warren T. Berry has made some interesting experiments with this type of davit.

There is another type of davit touched on in this paper, viz., the round-bar davit, that is turned by a worm and wheel. This device is passed over as being of soem assistance but has but one reach or overhang. This is not correct. as with this type of gear a lifeboat can be placed anywhere within the range of outreach of the davit from a point where the gunwale of the lifeboat is flush with the side of the ship in the extreme throw of the davit.

This particular boat-handling device referred to is the Irvine handling gear. The rapidity with which a lifeboat can be handled with this gear was illustrated in a recent collision between our steamer Commonwealth and the Norwegian tramp steamer, Volund. This collision happened about one o'clock in the morning on September 26, 1908. Immediately after the collision a boat crew from the Commonwealth was called, a lifeboat launched, and the entire crew of the Volund, consisting of fourteen men, were rescued by the Commonwealth boat before the Volund sank, and when it is considered that the Volund sank six minutes after the accident, there can be no doubt of the efficiency of this lifeboat handling gear.

I happened to be on board the Commonwealth on the night of this collision, and to my mind, far more important than gear for handling lifeboats or even the lifeboat itself, is to have vessels so designed that it will be well nigh impossible for them to founder.

Next to the design of the ship is the necessity for a trained crew. With a trained crew there are many types of boat-handling gear that are efficient, and without a trained crew, the best and most elaborate boat-handling gear will be inefficient.

There is another matter Mr. Forbes drew attention to, however—the time required to seing the old-type davits out from the boat; and I want to say that the United States law is very clear on this point and requires that "All lifeboats shall be fitted with such davits and gear as will enable the boat to be safely launched in less than two minutes from the time the clearing away of the boat is begun."

Even the old type of swinging davit fulfils this requirement when operated by a properly trained crew.

Mr. A. P. Lundin, *Member:*—I am quite pleased at the general interest manifested in this paper. It seems to have created almost as much discussion as the steam turbine usually causes in this assemblage.

It is singular that the discussion so far seems to center in the different types of davits, whereas, in my opinion, the proper way to consider this question is as a whole, *i. e.*, in order to get a really efficient and practical boat equipment it must be considered in a scientific and systematic manner, both as regards lifeboat construction and davit installation for handling them, not to mention other accessories such as chocks, blocks, tackles and releasing gear, etc.

This problem is not as easy to decide as might be supposed; there are certain difficulties to overcome, in the solution of which it might be well to profit by the experience and co-operation of an old tar, or of those who are really experienced in launching and handling boats in all kinds of weather and conditions.

In looking back over my various experiences of twenty years at sea, I might say that it would have been well at times if I could have had some of you here present with me. I have found that there are times at sea when all the science of engineering and clever ingenuity of navigators count for less than a strong stomach and a steady hand; for instance, when you are hanging by your eyebrows to a yard-arm, trying to reef a top-sail, with the ship rolling so heavily that your particular yard-arm is describing an arc of 100 degrees or so; or when you have to be in the fire-room and the bilge pumps are out of order and your ship wallowing about so that the bilge water swamps the floor plates and bakes into them before the fires of the boilers, causing an odor that nauseates all but the strongest; and finally, when you come alongside a large vessel in a lifeboat filled with humanity and the sea running so high that one moment you think the onrushing wave will land you on the deck while in the next your little boat is trying to dive under the bilge—all these are moments when sound stomachs count for much, because dizzy heads and nerveless fingers cannot do the work at such times.

Considering all this, in order to get up something that is efficient and really useful in the way of lifeboat equipment, it will be advisable that naval architects and engineers work in co-operation with sea-faring men.

It is pleasing to note that during the last few months the U. S. Government, as well as other governments, are taking a little more interest in this matter; they are beginning to give the details of the construction of lifeboats due consideration. It is to be hoped that in the future it will not so much be a question of how much a boat or a pair of davits cost but quality and efficiency will be considered, which is the most important matter.

Mr. Forbes' paper is very interesting, yet I cannot quite agree to all that he says. It seems to me, offhand, that his paper looks somewhat mixed. As regards his belief that at least some of the lifeboats should be equipped with one-man hoisting and lowering controls, I cannot agree with him on this point. I have personally had the experience of coming alongside ships with lifeboats in a rough sea and believe even Mr. Forbes, had he been present, would have been glad to leave the hoisting to those on deck who were standing on a firmer footing.

As regards the argument that the sea may be so rough that it would be foolhardy to try to hoist a lifeboat at all with the people in it, this may be true, but an experienced seaman can always find ways and means. For instance, around the Hawaiian Islands and the coasts of Central and South America, where most of the harbors are open roadsteads and ships have to ride at anchor, they roll and pitch about when embarking or disembarking their passengers in small boats. The way they do it there is to swing out one of the cargo booms, or else a crane, and transfer the passengers in a specially designed basket. This is done in all kinds of weather.

I quite agree with Mr. Welin that for ships of ordinary heights substantial bollards for lowering with Manila falls are as good as anything, and if it is desired to facilitate boat drills and hoist boats quickly and at a minimum of time and labor, this can best be accomplished by power capstans, to which the boat falls can be led. For very large ships, however, where the boats are chocked from 60 to 80 feet above the water-line, it is a different matter, and there it may be necessary to utilize some mechanical means and lower the boats with wire falls; in such case I believe that a system like the one devised by Mr. Welin for the S. S. Imperator will cover all requirements.

In discussing this paper a great deal has been said about stresses on the different types of davits, and some criticism has been offered as to the way of calculating said stresses. I personally know the man who did this work, as regards the Welin davits, and I know also that we have fitted thousands of davits and have found his mode of calculation correct. The safest way to go about it, when rigging up special gears for heavy weights, is to lay the stresses down graphically. However, the gentleman who criticized this work has not offered any better solution.

Now, as you all know, I am the representative of the Welin quadrant davit. I did not start to introduce this davit in the United States without due consideration. I first had my patent attorneys send me copies of all the patents for davits which had been issued during the last twenty years; they came pouring in rapidly until they reached close to 2,000. I asked the attorneys to stop. I found there were close to 200 which had actually been manufactured and fitted; none of them, however, survived the experimental stage. As soon as we took up the Welin davit, practically all of them were replaced with it. There are about 6,000 sets of Welin davits in use. Some of these were installed on ships which went down at sea and their efficiency was put to actual test. In all cases on record, the davits performed the work rapidly and efficiently, no matter what the weather conditions were.

It is not a matter of sentiment with me; if to-day or to-morrow a better set of davits should appear, I would be one of the first to take an interest in it, even to the extent of investing, because I am firmly convinced that nothing can be too good, either as regards lifeboats or davits.

In conclusion, I add a few words to the discussion on lifeboats. The principal objection offered is that lifeboats are of no use except in smooth water. To those who hold this theory, I wish to point out the fact that sailors, *i. e.*, really experienced seamen, who know how to handle a lifeboat in a high sea, place far more confidence in them than architects and engineers who lack practical experience in handling

boats in rough weather. One thing is certain—it takes a good sailor to make use of a lifeboat under severe conditions and it might be well for the technically trained engineer to consult with a practical old salt when considering this important subject.

We need only refer to the statistics of the various governments to convince ourselves that thousands of lives are being saved by means of lifeboats in rough as well as in smooth water. The U. S. Lifesaving Service saves many lives every year by means of lifeboats, and under the most adverse conditions. Statistics show that in most shipwrecks very few lives would be saved if lifeboats were not available.

Further, I want to point out how much work is actually being done on the high seas in small boats. Take for instance the cable ships, which are often compelled to continue their work in a rough sea; a great deal of this work is done in small boats which are far inferior to a lifeboat. The fishermen on the banks of Newfoundland and elsewhere do their work year in and year out in small dories which might be considered very unsafe and difficult to handle as compared to a lifeboat. I think this should be sufficient to refute the statement that lifeboats are of no use in rough weather.

Mr. Mason S. Chace, *Life Member:*—I have been much interested in what Mr. Forbes has said about the desirability of having the best possible equipment of reliable lifeboats in sufficient number, also the necessity of having the davits or other launching apparatus for these boats strong, simple, and under perfect control. The steel boats of the Lundin type would seem to fulfil the requirements of a strong, seaworthy lifeboat, and one which can be nested in groups of at least two to economize deck space, and economy of deck space is an important matter. I would like to ask Mr. Forbes what the weight of these lifeboats per person accommodated is. I have noted from some figures published in connection with the investigation of life-saving appliances by the Board of Trade in England that the weights given for open and decked lifeboats, also life-rafts, per person accommodated ran from 68 pounds to 72 pounds and over. The weight of collapsible boats was given as about 40 pounds per person accommodated. This item of weight of boats and weight of davits and other launching appliances is a very important one.

The stability of many existing ships would be seriously compromised by the addition of as much top weight as sufficient lifeboat accommodation for everybody would necessitate. Of course, this condition can be met be reducing the number of passengers carried to correspond to the lifeboat accommodation which can be provided.

The innovation introduced by a Japanese line of passenger steamers, running across the Pacific, of giving every passenger a ticket to a certain lifeboat seat may give some timid passengers a new feeling of security, but many will have their confidence in the safety of ocean travel much shaken by this innovation. Such a system of tickets for lifeboat seats will certainly give all passengers a new interest in them. I do not believe, as Mr. Forbes has suggested, that the perfecting of

life-saving appliances will cause those in command of vessels to become over-confident or careless.

I believe that the important lessons of the Titanic disaster are:—First, the necessity of eternal vigilance on the part of the navigator as the price of safety. Second, that naval architects and shipbuilders should make merchant ships, particularly passenger steamers more secure against damage by collision, both in the way of additional strength of construction and additional water-tight subdivision. Ships can be made much safer than they are at present, although the day of the practically indestructible ship has not yet arrived. Lastly, provide sufficient lifeboat accommodation for everybody, but remember that when an accident to a vessel occurs under severe weather conditions, such as are often met with in the North Atlantic, particularly in winter, that many of the lifeboats provided are likely to have been damaged even before they are launched, and that life in the boats would be so unbearably hard that most people would prefer to go down with the ship rather than attempt to go into the boats, even if it is not absolutely hopeless to attempt to utilize them.

Mr. Spencer Miller, *Member:*—Mr. Forbes' interesting paper deals chiefly with davits and boats for life-saving, and the discussion on this paper has been confined to them.

Life-saving at sea is of paramount importance. Lloyds reported 562 ships lost in 1911 and, strangely enough, a corresponding number in 1910. With such a loss of ships per annum surely there must be a great loss of life. According to the statistics published by the Life-Saving Service in America, 62 per cent of all the ships having casualties at sea during the year 1911 occurred when the sea was rough, too rough, in fact, to permit the employment of any ship's lifeboat. It may, therefore, be confidently asserted that in more than half of the circumstances where life-saving applicances are needed at all the ship's lifeboats cannot be used.

Are we not led to regard the lifeboat as a reliable life-saving appliance because so successfully employed by shore life-saving crews? The surf lifeboat is manned by picked crews. They are masters of surfmanship. The work of rescue effected by these men is one of the marvels of the day. The common ship's lifeboats have no such crews nor is it practicable to have heavy sea drills at sea.

Since the advent of the wireless telegraph, laws have been framed in nearly all civilized countries demanding that passenger carrying steamships be equipped with the wireless telegraph. Furthermore, the law requires that ships shall respond to calls for help. Every passenger ship, therefore, becomes a life-saving ship and should be equipped with the most approved appliances for effecting rescues in a heavy sea.

When a wireless call comes for help the steamer proceeds to the rescue, but when it arrives, in more than half the instances it is unable to render assistance because it has no implements to employ in a heavy sea.

It is right here that I desire to speak on behalf of a new marine breeches buoy

apparatus which I have been giving considerable attention to in the last few years. This apparatus has been perfected and two revenue cutters are equipped with it.

The chief point of difference between the new marine breeches buoy apparatus and the common shore breeches buoy apparatus resides in the addition of an automatic tension engine which is a take-up and payout device for the supporting hawser. This engine was originally developed to meet the demands of the U. S. Navy Department in connection with the marine cableway for coaling warships at sea. The automatic tension engine for life-saving is much smaller in size, and is capable of much higher speed of take-up. This apparatus is to bridge the gap between the rescuing ship and the wreck; it maintains a uniform tension on the connecting hawser. The distance between the ships may vary from 100 feet to 1,500 feet. It will compensate not only for the pitch and toss of the vessels but also for the distance between the two ships which will vary while maneuvering. It will be impossible to snap it. A man desiring to break a string with his two hands first slackens (bringing his hands together) then quickly separates his hands and the line parts. A line that never slackens cannot be broken half as readily as one that is allowed to slacken. The very fact of a slight increase in the strain on the connecting hawser automatically produces a reduction in the steam pressure which causes the automatic tension engine to pay out the rope as demanded. If the increase in tension is violent the decrease in steam pressure is correspondingly great. If the increase in tension is gradual the steam pressure is reduced gradually. Thus the pulling on the hawser pulls down the steam pressure and hence the uniform resistance. Slackening on the connecting hawser increases the steam pressure and the line is wound in.

There is nothing new about the breeches buoy.

More than half the wrecks of the world are of schooners with small crews. More than half the wrecks of the world are ships of less than 700 tons tonnage, consequently the ordinary circumstances in which this marine breeches buoy apparatus would be employed would be for the saving of only a few lives. The advantage to the steamship fitted with this appliance in answering a call for help is that the rescue can be effected in the shortest time and with certainty and safety.

Mr. James R. Raymond, *Associate:*—I beg to differ with Mr. Forbes on the question of detaching boats, particularly when he says: "If perfection is looked for, such a gear must be so made that by the action of one person in the boat a release can be instantaneously effected at any time." To my mind a device so constructed, as to permit of a boat being detached at any time, possesses a most dangerous feature. There are many instances of disastrous failures attended by most serious results, due to not pulling the lever or lanyard controlling the device at the proper time. In the time of excitement it is impossible to so place the people in the boat as to trim it properly: the man at the lever, especially at night, cannot judge of the distance his boat is from the water, pulls or throws his lever and, instead of releasing his boat when in the water, which is the proper time to release it, releases it when it is a distance from the water, making a launch that is disastrous to the

occupants. Many instances are on record where boats so fitted have been released while at the davit heads by some one who thought he ought to do something, and he did it.

In my opinion a device for releasing boats, that depends upon someone doing a particular thing at the right time, at night, in a crowded boat with everybody excited and a condition of sea that would call for the greatest coolness on the part of the operator, is not so desirable as one that is reliably automatic and at the same time is under the control of the men in the boat, if required. There are numerous devices that can be operated by one person, when the boat is water-borne, but not until then, when there is a strain put on the falls by the sea they cannot be detached until there is slack given to the falls. This does not always permit of the boat being detached, when it should be, instantly; not will a boat so fitted be detached with any certainty while the vessel is under way or in a strong current, for the reason that the lever may not be thrown, or the lanyard pulled at the right time.

Again, the reasons given by Mr. Forbes for not favoring an automatic gear, namely, "because the moment the boat becomes water-borne the releasing gear detached, and unless the boat is held by the painter, she is adrift," etc., are points to my mind commendable in a detaching device, for the reason that a boat crewed up and lowered should get clear of the side as soon as possible in order that it may avoid being smashed alongside.

Mr. Forbes says, "There are times when it is not desirable that a boat should be released the moment it is water-borne." When would this be? Could it not be held alongside by the painter and ride more safely rather than being held by the falls particularly if the sea was bad and the blocks, boat and gear weighty?

In conclusion my idea of a releasing device for boats is one that is reliably automatic and can be controlled by the men in the boat, if required, with the falls so rove as to allow both ends of the boat to detach when either end becomes water-borne, irrespective of which end of the boat strikes the water first; and yet which can be readily and quickly hooked on, from the boat or deck, with the least danger to the men in the boat, is what is wanted and such a device is in existence and is now in use.

Mr. Harry W. Broady (Communicated):—Mr. Norton's and Mr. Berry's arguments against the Welin quadrant davits were very interesting, and also their reasons why they believe Mr. Norton's design is the last word in davits.

The Broady turn-buckle davit was built for a yacht where the lack of space made it absolutely impossible to use any other davit. The location of the center of the screw support could not be in any other place, and the length of the arm was given for the necessary long outreach. The bevel gears were required on account of the only available space for the cranks, and the bearing support for the lower end brackets was more than ample because the center line of load came inside the bearings of one and only half an inch outside the other bracket. The davit was made for practical use and not for demonstration or show purposes. Only about 30-

pounds effort on each crank was required to swing the boat in its most unfavorable position, that is, going inboard.

A clear deck with ample room to put up a standard davit is not always available.

The tables and diagrams given by Mr. Forbes in his paper are not to be confused with the Broady davit. This paper was a comparison of davits designed on Mr. Norton's theory and the practical quadrant davit. Mr. Norton refuses to accept the figures and data given by Mr. Forbes, but he will find it difficult to show the data given incorrect. The diagrams given were arrived at in a scientific manner and give exact theoretical comparative values. In the formula given, it should be noticed that the values are given for friction in the screw, and other resistances, tending to decrease the efficiency of the davits.

Welin davits roll on the quadrant flanges and do not in any way slide. The weight is carried by this flange and the function of the rack is only to control the swing of the arm. The friction in the rack is therefore only the ordinary spur-gear friction. The arm of the Welin davit is supported sidewise by the tie-rod at about one-third of its height from the lower end which is guided by the quadrant flange. The Norton davit arm, on the contrary, is supported sidewise only at the lower end and depends altogether for its steadiness on the length of pin and the location of bearings. It is not supported in any way by the sleeve or screw in a sidewise direction. The advantage in having the arm supported at a high point as in quadrant davits is obvious. The deflection in the arm is also lessened by this arrangement on account of the comparatively short arm above the pivoting point.

In the Welin davit it is impossible for the boat, in any position, to hit the screw, it being protected by the top brace of the framework; in the Norton davit screw, the screw, for a considerable part of the boat's travel, is entirely unguarded against a blow, and it may easily be put out of order by the slightest blow from the boat, which is likely to occur in rough weather.

In the Welin davit the screw has been designed with the utmost care. It is supported by means of stationary bearings at each end, giving rigidity in all directions as against the screw in the Norton davit supported only at one end and then by a swivel bearing. This would not cause any serious objection if the screw on the Norton davit were subjected to tension only, but it is under compression through about 45 per cent of the travel. It is impossible for working purposes to make the nut fit absolutely snug on the screw, and the nut sleeve must be given considerable clearance in the end supported by the arm. It is clear that this construction, when under compression, must give a very dangerous blend in the connection between the screw and the nut sleeve and this means an ever-increasing wear, bend and friction. The importance of this cannot be too strongly emphasized. I maintain that all such types of davits would be out of order or have to be renewed in less than five years by the general wear and tear of the numerous boat drills required.

In the Welin davit the thrust is taken up by a solid column, *i. e.*, the screw, and the thrust is the only stress taken up by the screw as all other stresses are taken up in the tie-rod and in the rack arrangement, which are all stationary.

The stationary tie-rod is fitted with a brass sleeve on which the nut is sliding.

Mr. Norton placed undue importance on the bending effect in the nut due to the fact that the screw and the supporting tie-rod do not have the same centers.

Among the models shown at the meeting was one that had a screw in the center of the support; this design is adopted in appliances where great stress is laid on keeping the resistance as small as possible. It is not done on ordinary davits, however, because it has been found unnecessary by actual tests. The arm is guided by the nut and rolls on the quadrant flange in the groove; the nut is supported by the tie-rod so that it cannot bend; but only slide.

In all types of davits, ample clearance must be given, owing to the rigid and solid construction. This can be done in the quadrant type but, on the other hand, in the Norton davit such clearances must increase wear and tear, owing to its less rigid construction.

The diagrams of Mr. Forbes' paper were figured under absolutely the same conditions for both types of davits; the same swing, the same boat weight, the same crank radius, the same screw center-line and the same screw. The latter is very important, everything being figured on the dimensions of the standard Welin davit.

It has to be remembered that when this Norton davit is swung out the length of the connecting screw and sleeve is about 8 feet, and it is not supported in any way except at the ends.

The objection Mr. Norton made to the open construction of the screw, tie-rod and rack on the Welin davit is one that was made while it was practically unknown; is no longer criticized, but is considered a great advantage.

A glance shows whether everything is in running order on the Welin davits; in the Norton davit it is impossible to see the condition without unscrewing the entire davit for inspection. It would, however, require a great deal of paint to obstruct working of the screw as Mr. Norton suggests, with the ample clearance given in the Welin davit.

The Welin patented chocks are very simple and make a substantial bed for any boat. The gripes that hold the boat are connected to the chocks and are released automatically when the outside chock-block is folded down. It must be remembered that in swinging the boat out neither the Welin nor Norton davits give a straight upward lift only, but an outboard swing also, therefore stationary chocks of sufficient height would be in the way.

The Welin compensating arrangement was not mentioned by Mr. Norton. This arrangement gives the boat a straighter path of travel than does the Norton davit. In the latter the boat has almost the same path of travel as the top of the davit. Both davits at the start give a rising curve, but with the Welin compensating arrangement this is not higher than is required to clear the chocks and then the path of travel slopes gradually downward and outboard. With the Norton davit it is more of a jump. This compensation is of great assistance when taking the boat in, and it is on this account that the power needed for swinging in a boat on the Welin davit is only 75 per cent of that needed with Mr. Norton's davit. The Norton has about one-third more working parts than the Welin davit, minor

details such as bolts, nuts and screws not included. I agree that the pin-davit looks more simple and also weaker. This weakness does not belie its appearance, but its simplicity is an optical illusion.

The frame of the Norton davit is twice as long as that of the Welin davit for the same conditions, taking up twice as much deck space.

Welin davits have been made of structural steel but are used only on small sizes. If one considers its working principles, the theoretical advantage of the Welin davit is very marked. The arm goes over to the place where the load is, picks it up and goes to the extreme outboard position, thus swinging the load to the desired place, whereas the arm in the Norton davit, being pivoted, remains at the same point, stretches as far inboard, takes the load on the long outstretched, unsupported arm, swings the load to position, requiring about four times as much work.

For simplicity, substantial construction and reliability the quadrant davit remains as yet unsurpassed.

Mr. Forbes:—The idea of this paper was to suggest something about life-saving appliances, and I laid down certain requirements. I do not think any of those who have discussed the paper have disproved my ideas or found them incorrect. Captain Lundin, I think, misunderstands my idea of boat control. It was not my idea that the apparatus should be in the boat itself, but on the deck of the ship, with a connection in the hands of the man in the boat.

Mr. Berry has found that the hencoop system does not please him very much, and I think with him it would take a good deal of nerve to stay on the deck of a boat, even if it was ashore, with a platform that was being knocked out from under you, and I rather trust to the hencoops. The Welin davit is known to me as is the worm and wheel-moved davit. This last-named davit has no suitable variable outreach; it has merely a variable outreach, but it is in the arc of a circle.

Mr. Norton's sheath davit is an excellent davit, but I fail to see why we need the sheath in protecting the screw if the force of the boat striking it would not bend it. The Commonwealth, at the time that the accident referred to by Mr. Gardner occurred, was in perfectly calm water, and the crew were able to get the boat down in quick time; just what I stated was to be expected. But it must be remembered this was in smooth water.

It seems to me that my paper stands this way—I have discussed certain things for the purposes of life-saving which are ideal, and which ought to be worked for, even though it may not be practicable to reach them at the present time.

THE PRESIDENT: We have received the following telegram:—

"STEVENSON TAYLOR, President,
29 West 39th St., New York.
"Thank you for telegram, and may I, through you, thank the Society for the great compliment paid me. I accept with pleasure the invitation to the banquet to-morrow evening, Friday, at the Waldorf-Astoria.
ROBERT M. THOMPSON."

Referring to the banquet, I am informed that there are two hundred and forty tickets taken, and only a few are left. A meeting of the Council will take place to-morrow at the close of the morning session. The morning session will commence promptly at 10.15, so please be on hand.

FRIDAY MORNING, NOVEMBER 22, 1912.

President Stevenson Taylor called the meeting to order at 10.30 A. M.

THE PRESIDENT:—It is a great pleasure, gentlemen, to say that we are honored this morning with the presence of Col. Robert M. Thompson, the gentleman yesterday elected to succeed the present president as president of the the Society of Naval Architects and Marine Engineers. Permit me to introduce Colonel Thompson.

COLONEL THOMPSON:—Gentlemen, I am very glad of the opportunity to thank you for the honor you have conferred upon me. It is well that you should know at the very last moment how much you are losing when you are losing your retiring president, and how little you are receiving in return for it, but I promise you that I will do my best to further the interests of the Society and, after all, "Angels can do no more." (Applause.)

THE PRESIDENT:—The next business in order is Paper No. 7, entitled "The Preservation of Metals used in Marine Construction," by Lieut.-Commander Frank Lyon, U. S. N.

THE PRESERVATION OF METALS USED IN MARINE CONSTRUCTION.

By Lieutenant Commander Frank Lyon, U. S. N.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

In taking the above title for this paper the writer intends to apply it to vessels only under the two subdivisions:—

The metal of the hull.

The metals of the engines, boilers, and machinery accessories.

The causes of the wasting away of such metals are three:—

1. Corrosion.
2. Abrasion.
3. Erosion.

Corrosion is the most serious of the three, is ever present, and is the most difficult to combat.

Metals are weakened by all of the three causes and also by the continued variation of stresses in them. These variations tend to open up and emphasize the inherent defects in the metals due to segregation of the impurities in them and to their different physical characteristics which are induced or produced by the different temperatures at which they are worked during stages up to and including the finished article.

Corrosion, the chemical decomposition of metal, is due to the differences in electric potential between the metal and the liquid or moisture that wets its surface. It is produced only when the metal is wet or moistened by some liquid of lower potential than metal itself. Metals that are absolutely dry do not corrode, and wet metals corrode only on their wetted surfaces.

In this paper it is assumed that there is some definite, absolute zero of electrical potential similar to the absolute zero of heat, and that all bodies and liquids have some definite potential at each temperature. When a metal at a certain potential is immersed in a liquid of lower potential the metal dissolves with the liquid and raises its potential; if the metal remains in solution in the liquid until the potential of the liquid solution is the same as that of metal, the solution is then saturated and no further dissolving takes place until the conditions of temperature or liquid solution are changed. If the potential of the liquid is the higher, the liquid exerts an electrical pressure on the metal but does not cause it to dissolve. If the metal can dissolve in the

liquid but is thrown out of solution as rust by some chemical agent inherent in neither the metal nor liquid, the dissolved parts do not raise the potential of the solution and the dissolving goes on to the extinction of the metal. The same results will be attained if the liquid is changed as fast as the metal dissolves into it, such as a plate on the side of a ship in a large body of water.

The diffusion of the dissolved parts of any substance in a liquid is believed to be due to the fact that the potential of the liquid is raised at the dissolving point and that the tendency of all parts of any liquid body at different potentials is to equalize or come to a common potential. This in itself tends to keep the potential of the liquid at the dissolving point down until the potential of the whole body of the liquid is brought to the same as that of the dissolving substance. That is, the liquid becomes a homogeneous solution throughout its whole mass by diffusion of the dissolved parts into the solvent.

If a metal has all of the points in its wetted surface at the same potential, and that potential is higher than that of the liquid by which wetted, it will corrode or dissolve at all of its points and general corrosion is said to exist. If the potentials of some of the points are higher and others lower than that of the liquid in which it is immersed, it will corrode only at the points where its potential is higher than that of the liquid, and local corrosion is said to exist with pitting of the metal as a result.

The potentials of pure metals and liquids vary with their temperatures and with the way in which they are stressed, and those of impure metals and solutions vary in the same way, and also with the way in which the ingredients vary with the temperatures. That is, an alloy would not have the same potential that any one of its ingredients would have at the same temperature, but one common to that of all of the ingredients. Also, the potential of a solution at any temperature would not be the same as that of either the liquid or dissolved substance at that temperature, but at some one potential common to them both. In other words, the theory of potentials is assumed to be similar to the theory of heat. If two bodies, solid, liquid, or gaseous, at different temperatures are brought near each other they assume a common temperature in proportion to the amounts of heat each contains, and it is easily conceivable that the same objects at different electrical potentials would come to some common potential in proportion to some inherent qualities of the two bodies in question.

If two metals are connected by a metal conductor and they are immersed in a liquid, and if one of them is at a potential higher than the liquid and the other at a lower one than the liquid, the higher one dissolves into the liquid and raises its potential, the liquid discharges its potential to the one lower

than itself, and a current flows and the original condition is maintained. If the metal connection is broken, then the metal of higher potential raises that of the liquid, which in turn raises that of the metal of the lower potential, and eventually the potential of the whole becomes equal to that of the higher metal, no current flows, the original condition is destroyed, and the metal-water-metal series is polarized. A metal with different potentials at points in its surface immersed in water or a water solution acts in the same way. If all of the points are higher than that of the solution they all corrode until the potential of the liquid is raised to that of the lowest point on the metal. As the points of higher potential dissolve into the liquid and tend to raise its potential, the liquid then discharges its potential to the points in the surface lower than itself, a current flows from the high point to the liquid, from the liquid to the metal at the points lower than itself; the circuit is then complete and local corrosion as pitting is the result.

This discussion on corrosion is made necessary by the subject-matter that is to follow. The statements made above will be referred to in many places and would not be understood unless explained beforehand.

Abrasion is due to the wearing away of one substance by rubbing against another. In vessels' hulls it is mostly noticeable on the bows where rubbed and abraided by the anchors and chains. In their engines and machinery it is noticeable in the bearings, guides and similar construction, especially when not properly cared for. Its effect on the hull material is not serious and cannot be prevented in wake of the anchors and chains. There is no danger of damage from that source.

Erosion is due to the wash or scouring action of liquids or gases over metal at high velocities. With the exception of valves, and maybe in a few other places about the machinery, its effect will not cause sufficient loss to be noticeable.

Metals used in the construction of the hulls of vessels are: Steel for plates, angles, beams, rivets, struts, and external and internal braces and hull fittings. Composition castings for sea chests and propellers. The compositions generally used are manganese and phosphor bronzes; monel metals (nickel bronzes) and an 88 copper, 10 tin, 2 zinc bronze.

Steels are extremely variable in the way in which they corrode and in their effect upon other steels to which they are connected by metallic contact. These variations are due to the differences in chemical compositions and to the difference in state of stress of the molecules of the metals in their wetted surfaces. These different stresses are in turn due to the different workings the metal has received, the temperatures at which it has been worked, and to the heat treatment finally given the finished product.

Two pieces of steel from the same plate may vary perceptibly in the way in which they corrode and in the loss of weight per unit of area in a unit of time due to the above causes; that is, certain constituents may be segregated over the surface of one piece and not over the other, or different stresses may exist in the two surfaces, due to the different ways in which they have been worked or treated. An angle bar corrodes more quickly than a plate of steel of practically the same constituents; a bent plate or angle bar corrodes in and near the bend more quickly than the straight part. There is always more corrosion around the entrance, run and bilge of a vessel where all of the hull plates and frames are bent, than along the straight body. A rivet that has been hammered and upset corrodes faster than the same rivet before it was hammered. The assumption that any piece of steel is a homogeneous body either as to chemical contents or as to physical stress is one that can very easily be disproved by sufficient chemical analyses and by photomicrographic work. The writer was much surprised to note the differences in chemical composition and photomicrographic results in a boiler tube, samples taken (1) over the expanded surface and (2) over the unexpanded surfaces. He was also surprised to see the different ways in which boiler tubes corroded over the same areas, as shown both by Cushman and Walker's ferroxyl mount and by actual immersion. Steels are of higher potential than water at ordinary atmospheric temperatures.

Copper and copper compositions vary in the way they corrode. These variations are due to chemical compositions, variable temperatures, and to the way in which they have been worked, producing stresses in the surfaces of the finished product. At ordinary atmospheric temperatures copper and its compositions are of lower potential than water, *i. e.*, they are said to be electronegative to water. As their temperatures are increased or as they are stressed to higher degrees their potentials increase faster than does the water in which they are immersed, and if the temperatures or stresses are raised sufficiently they become of higher potential than water and corrode or dissolve similarly to steel. As a proof of this, from observation on shipboard for thirteen years, copper and composition piping corrode faster at the bends and near flanges that at the straight parts, and pipes in which the temperatures are different in different places, such as feed piping through feed heaters, condenser and circulation piping, and other piping which is at different temperatures over different parts, corrode faster than do the fire mains and other piping which are at the same temperature throughout. Two pieces of copper or composition cut from the same plate, treated in the same way, may show no difference of potential when immersed together in water and connected through a potentiometer. Then if one piece is

removed and hammered, worked or heated, and replaced, it will show that it is electropositive to the unworked piece, and it will corrode if placed in water of a certain temperature in which the other piece may or may not be affected according to the treatment and chemical composition of the original sample. Composition castings are generally of a very uniformly stressed surface, due to the heat treatment naturally given in coaling. Those placed as sea chests in ships require no protective coating and seldom if ever give any trouble, the highest temperatures to which they are subjected are not sufficient to raise their potentials to equal that of the sea water in which immersed. If the copper compositions are segregated and these segregated spots are of higher potential than sea water, they dissolve away and pit to the depth to which the segregations extend.

These compositions are negative or lower in electrical potential than ordinary or sea waters, while steels are electropositive or of higher potential than the same waters at ordinary temperatures. If the bare steel is immersed in the water it will corrode or dissolve at all points in its wetted surface, while the composition casting in the same waters will not corrode at any of its points. If these two metals are connected by a perfect metallic contact and immersed in the same water, the rate of corrosion over the steel will be greatly increased. The rate at which it will be increased all over its surface will depend upon the perfection of the metallic contact; if there is no such contact the presence of the composition will not increase the rate of corrosion on the steel, no matter how close together they may be. If the steel is covered with a moisture-proof paint and the same contact as above made, it will not corrode when connected by a perfect metallic contact with the compositions, but if the film of the moisture-proof paint is broken so that any part of the steel surface is exposed to the water it will corrode rapidly over the exposed part.

Where these composition castings are secured to the steel hull of a vessel it is customary to secure plates or rings of rolled zinc as a protection to the steel, the idea being that the zinc being of higher potential than the steel, will corrode and preserve the steel. That this assumption is thought to be correct is evidenced by the great use of zincs at a very large cost in these places. Yet the writer has failed to see that the assumption is positively correct for the following reasons: (1) Zinc quickly corrodes and becomes covered with zinc oxide, and zinc oxide from boiler, condenser and hull zincs has been found to be electronegative to steel in every case tried. (2) In no case has the writer ever had a piece of steel connected to a zinc plate corrode less in the same water in thirty days than a piece of steel from the same plate placed alongside the first plate, but not connected to zinc.

(3) The steel around the sea chests of the bottom blow discharges, if properly painted, does not show more corrosion than does that around the other discharges, and the writer has never seen a ship docked that had any zinc in the bottom blow discharges, they evidently having deteriorated and been blown out soon after the previous undocking. (4) It has been noticed on many occasions that the only steel attacked by corrosion in the vicinity of the zinc plates was that of the steel screws holding the zincs in place. Therefore the writer fails to see the necessity of the zinc protectors, especially as he has just seen the bottom of a ship on which, after having been in the water over six months, there were no signs of corrosion at any point except on the zinc, when the paint film was unbroken.

The use of zincs and other metals electropositive to steel in galvanizing, electroplating, or other similar covering processes, as a preservative for it, when continuously immersed in water, is a dangerous one and is not to be commended for the following reasons: (1) The metal covering must be electropositive to the steel or metal to be protected, therefore it is more soluble in water and will dissolve more quickly. (2) When the steel is once exposed to the action of the water it corrodes rapidly over the exposed surface and, if not stopped by some similar covering, it will pit through before other surfaces are uncovered. (3) For hull and ship fittings generally a surface once exposed cannot be again covered. (4) The stable oxides of all metals are lower in the potential series than the pure metals, therefore the oxide of the coating may be lower in potential than the metal to be protected and actually does harm instead of good where the steel is exposed.

For the protection of the hull construction it therefore remains only: (1) to provide the most homogeneous metals possible both in regard to chemical composition and physical structure. (2) Paint the completed structure with a complete film of the best anti-corrosive paint that can be obtained, after having cleaned the surfaces of all foreign matter and rust and dried them thoroughly. After this film of paint is dried give the surfaces a second coat of the same paint; after this coat is dry paint with an anti-fouling paint for all outboard, under-water structures and with the best moisture-excluding paint for all other surfaces. (3) Dock frequently and remove any rust that may be found, and repaint as may be necessary. (4) On inboard structures remove all paint that shows active corrosion under it and, when thoroughly cleaned and dry, repaint as before.

The subject of proper painting is a very important one and one that must be thoroughly understood to obtain good results. There are three necessary points that must be observed and understood as follows:—How to paint, when to paint, and what kind of paint to use for the different conditions the paint has to stand.

How to paint involves the question of the proper preparation of the surfaces, the proper preparation of the paint, and a proper spreading rate of the kind of paint used.

When to paint involves the question of the dryness of the surfaces and the atmospheric conditions in their vicinity. What kind of paint to use involves the question of whether the paint is to be used (1) as a protection to the metal (anti-corrosive and waterproof paint), (2) as a cleanser of the paint film of marine growth (anti-fouling or poisoned paints), (3) as a decoration to the structure (covering and coloring paint). In any of the above cases the paint film when dry should have about the same coefficient of expansion as the metal to be covered, or the painting will crack or become loosened from the surfaces, and any good effect, even unto decoration, will be lost. An anti-corrosive paint is one that, when well dried, is impervious to moisture and keeps the metallic surface dry so that no active corrosion can take place, and one that, when moisture does percolate through it to the metal, dissolves and raises the potential of the enclosed water to a point as high or higher than that of any metal exposed to it. To perform this last function the pigments of the paint must be higher in the electromotive series than the metal to be covered, and to perform the first the pigments and solvent must form a homogeneous film over the whole of the covered metal. An anti-fouling paint is one that, when any marine growth sticks on its surface, either poisons the growth and allows it to drop off or dissolves under the growth, due to its secretions, and allows it to loosen and float away. Decoration or distinguishing paints are those used to decorate the living quarters or to distinguish different kinds of piping. About the only requirement for them is that they must have a pleasing or distinctive color and the color must last as long as possible under the conditions of the service to which they are exposed. Many good anti-corrosive paints are not good waterproof ones; therefore, unless the anti-corrosive paint is a good waterproof one, it should be covered with a good waterproof paint, as the protective effect of a non-corrosive paint is obtained at the expense of the paint unless it is also a good waterproof one. As soon as enough of the paint is dissolved off to enable a free circulation of water to the surface of the metal the anti-corrosive effect is lost.

Proper painting is a most important aid in the preservation of metals and no effort should be spared to obtain it. The first cost of painting for the protective effect must be disregarded and the best paint obtainable for the purpose used and applied with the greatest care. There is a general tendency in some directions to regard painting as only for decorative purposes and to consider that the cheap paints frequently applied

are the best. Even for decorative purposes this is not true, because a proper paint properly applied will generally last at least three times as long as an improper one at half the price. Judging from the amount of surface to be covered, the conditions of its service, the number of men to do the work, and the other work they have to do, the best paint, properly applied, is none too good and should be obtained at any cost. The writer once put a coat of white enamel paint on the above-water sides of a gunboat in service on the Yangstze-Kiang River which lasted without retouching for over one year. It looked well all the while although washed daily with muddy river water.

As active corrosion cannot take place on dry metals it may often be better not to remove a good film of paint that has been put on over dry dust, and through which no signs of active corrosion are visible, than to spoil the paint for the purpose of removing dry and therefore harmless rust unless it is perfectly sure that a properly dried paint film can again be obtained over perfectly dry metal. The writer has on several occasions done more harm than good by removing good dry paint films previously put on over dry rust because he could not get the surfaces dry and a proper film of good paint to stick to them.

The metals used in machinery boilers and their accessories and piping are many such as—

Cast iron for cylinders and engine housings.

Steel for steam pipes, boilers, shafting, tanks, evaporators, condensers, feed pipes and general piping.

Composition for water boilers of pumps, water pipes, valve fittings, boiler fittings, condenser tubes and in other places.

Copper for small piping and in other places.

Monel metal for valve fittings, pump liners, pump rods and such other places.

Cast steel for superheated steam valves, slip-joint castings, etc.

Lead as a lining for iron or steel pipes.

Other metals are used but the above are the principal ones. The same observations apply to these metals that can be painted as previously stated for hull materials.

Oil films are moisture-proof when applied to dry metals, therefore there is very little if any corrosion taking place about an engine when it is in use. Paint around the usual main engines and their framing is unnecessary unless the engine is to be laid up for a long period, and, if used, is for the purpose of decoration only. The external sides of pipes, feed heaters, condensers, boilers, evaporators and tanks can be protected by proper paints. The

internal or water side of the above cannot be protected by paints nor is it generally believed by any other means, though lacquers, galvanizing, lead lining and other means have been tried on pipes, they have all proved unsatisfactorily, in some cases due to the unequal coefficients of expansion of the coating and metal, in some to the solubility of the lacquer, and in others to the fact that the metallic coating cannot be properly applied to the finished article. As the life of piping, boiler plates and other parts is no greater than the weaker part, the piece fails when improperly protected. Boiler, condenser, feed water, distiller, and evaporator tubes cannot be protected on either side by paints, lacquers, and coatings. Therefore all such parts should be made of homogeneous metals properly heat treated after being finished and then fitted properly so that the least possible internal strains are brought into it due to the fitting.

It has been definitely proved that any water made alkaline enough to show 3 per cent of normal alkalinity with calcined sodium carbonate is non-corrosive to steel at all temperatures up to 422° F. Therefore if the water in the boilers, tanks, evaporators and feed-piping is kept at or above that strength with sodium carbonate at all times, no corrosion will take place, while if the strength is allowed to fall to about 1.8 to 2.5 per cent, bad pitting will take place. In trying to reproduce the pitting continually taking place in boilers, tanks, piping and on bilge-plates with acid solution, or plain sea or distilled water, the writer failed in every instance on three grades of nearly pure irons, three grades of boiler steel, and on four grades of cast iron. It was easy to produce such similar pittings on all of them when immersed in weak alkaline and very weak carbonate solutions. For the above reasons it is believed by the writer that much more harm is done in enclosed metal vessels by water made slightly alkaline, either artificially or naturally, than is ever done by the small percentage of acids that ever enters the average boiler. Boilers and other water containing metal vessels or conduits containing acid water will go to pieces quickly, practically all over at the same time; those containing sea or distilled water will go to pieces all over at the same time but very slowly; those containing alkaline water of a strength not high enough to stop all corrosion will go to pieces in the weaker places, while other parts or places will remain perfectly good. If the percentage of alkalinity is high enough no corrosion whatever will take place. The reason for this is believed to be as follows:—

1. Water has a certain definite potential at any definite temperature.

2. Pure distilled water has a potential lower than that of steels, irons, and some alloys.

3. Acids added to pure distilled water at any temperature decrease its potential.

4. Alkaline substance dissolved in pure distilled water increases its potential.

5. The decrease of the potential of water when an acid is dissolved in it is due to the fact that the negative ion of the acid is lower in potential than that of the hydroxyl OH of water, the H ion being common.

The increase in potential of water when an alkaline substance is added to it is due to the fact that the metallic or positive ion of the alkali is higher in the potential series than hydrogen, while the hydroxyl or negative ion is common to both.

6. When any metal is wet by any water solution, if the potential of the solution is (*a*) higher than that of the metal at every point on its surface, the metal will not corrode; (*b*) higher than some points in the metal surface and lower than that in others, the metal will corrode only over the areas where the potential of the solution is the lower; and it will corrode faster over those points than it would if immersed in distilled water alone, due to the fact that though the difference of potential between that of the metal and that of the alkaline solution is less than it would have been in distilled water, yet the conductivity of the water has been greatly increased by the addition of the alkaline substance; (*c*) lower than that of the metal at any point it will corrode all over at the same time, faster over the higher potential points than over the lower ones. The rate of corrosion over all of the points will depend both upon the difference of potential between the metal at the point and the solution, and also upon the conductivity of the solution. As the alkalinity of the solution decreases, the difference of potential between the metal and the water increases and the conductivity of the solution decreases until pure water is reached. Any addition of an acid then increases the difference of potential between the metal and the solution and also increases the conductivity of the solution.

When considered with a given metal the potential of some alkaline solutions increase faster with a rise in temperature than does that of the metal, therefore a very weak solution that may not be dangerous at ordinary atmospheric temperature may be strongly active in the form of pitting to the same metal at higher temperatures.

Also a solution that may be strongly active to metals at atmospheric temperatures may be non-corrosive entirely at still higher ones.

The converse may be true with some of the alkaline substances, that is, a rise in temperature may not increase the potential of the solution as fast as it does the metal and a safe solution at atmospheric temperatures may be unsafe at higher ones. In the writer's experiments with alkaline solutions the general rule was that a one one-hundred-thousandth and a

one ten-thousandth normal concentration of alkaline solutions decreased the rate of corrosion of irons and steels slightly below that in distilled water and caused no pitting, while the one one-thousandth and one-hundredth concentrations increased the rate above that and caused very active local corrosion or pitting until the 2.6 per cent normal concentration was reached, when all corrosion stopped.

Cement washing the plates of drinking water tanks has its advantages but the washing must be done with great care, will not stick to paint, and is not durable. It must be watched carefully and renewed frequently.

The Cumberland Electrical Process appears to be the only way of preserving the interior surfaces of water-carrying pipes and circulating systems. It is on the same principle as the alkaline theory. The potential of the water is raised to a point higher than any point of the system by sending a current from an outside source to it from an easily replaced anode. The current must be at a potential high enough to raise that of the water to the proper point and must be kept on continuously. If the potential of the water drops below that of the metal at any point it will pit or corrode at that point similar to the alkaline solutions. This system will give excellent results when properly installed and properly attended.

The preservation of copper, composition or iron piping on board ships in the flushing, condenser and refrigerator circulating systems can be maintained by the Cumberland process if run by some electrical source other than the main power system of the vessel. This process has many drawbacks and requires constant attention. Except by making the piping and tubing of the best and most homogeneous metal obtainable, having it properly made and the finished article properly heat treated and fitted, it seems to be the only practicable plan available. It is sure if properly controlled.

The wrought iron, steel, and other iron manufacturers make many claims for their various materials, claiming maximum durability and resistance to rust. In thirty months of continuous testing of these various products it was interesting to note that in many cases one would show much better than another, but by varying solution, temperature, and treatment they could all be made to give practically similar results.

In waters that are made non-corrosive to iron or steel by alkaline solutions, their metallic contact with copper and other metals lower than iron in the potential series does not start corrosion, nor does the addition of free oxygen.

These notes and observations are made after thirteen years of active sea service as both an engineer and line officer in the U. S. Navy, and after nearly three years' work on corrosion problems at the U. S. Naval Academy. The writer offers them for whatever of interest they may be to anyone.

DISCUSSION.

NAVAL CONSTRUCTOR HENRY WILLIAMS, U. S. N., *Member:*—Commander Lyon has rendered valuable service in bringing before this Society the question of the corrosion of metals, also in elucidating the electrolytic theory as to its causes and the conditions under which the electrolysis takes place. I believe, however, that few of those present will be willing to accept his statements in toto, for while there is no question that fundamentally he is correct, differences will be drawn as to the conclusions and the interpretation of the various phenomena.

He treats of a subject that unfortunately has not received much attention from shipbuilders, except in so far as the effects of corrosion have manifested themselves in necessitating repairs.

Painting, which is the largest item of expense in the upkeep of ships, is required almost entirely by the necessity for preventing or at least checking corrosion. Commander Lyon states the necessity for proper painting, but unfortunately he places himself in the attitude of regarding the price of a paint as an index of its efficacy. He states also his opinion that the best paint is none too good and should be obtained at any cost. I am unable to agree with his view in these particulars. In my opinion, paint should be selected entirely with a view to its fitness for the purpose for which it is to be used, having in mind always the value of service which it is expected will be rendered. Where it is intended to preserve the metal in inaccessible locations, it is obvious that within reasonable limits the cost should not be considered in the effort to obtain the most effective paint. On the other hand, if it is a question of painting for decorative effect the exterior surface of a ship in a location that is easily accessible and that has already a number of coats of paint on it, consideration should be given to the probable time the paint will be expected to last before repainting ,and a cheap paint should be applied, if that will meet the requirements. However, I wish to emphasize my idea that the price is no index of quality of paint. I think often a cheap paint, properly compounded, has greater merit than the conventional high-grade paints made with linseed oil, turpentine, lead and zinc.

As regards the question of the use of zinc protectors, Commander Lyon appears to have lost sight of the fact that these zincs are put on for the purpose of protecting the steel from the electrolytic action produced by copper alloys used in sea chests and propellers. He states his experiments were by way of proving that the zinc had no effect in reducing the corrosion of steel alone. In order to demonstrate this point clearly, I have had prepared two small bars of steel with smaller bars of copper attached. On one of these couples the copper was surrounded by a frame of zinc. All were submerged in salt water, and the conditions may be regarded as exhibiting in an aggravated form the action that takes place continually between the steel of the ship and the copper in under-water fittings, as well as the protective

effect of the zinc. These samples, which I will exhibit, have been submerged only about seventy-two hours and show in a striking contrast the corrosion of one, and its absence on the other. That is the sample with the zinc on it (indicating sample), and that is the zinc protector. There is practically no corrosion at all on the steel. This sample, which has copper only, as you see, is badly corroded.

The statements as to lack of advantage of using galvanized steel plating is hardly borne out by the experience in connection with older torpedo craft, some of which had their under-water bodies built of black plating. These have corroded much more rapidly than others where galvanized plating was used.

Another point to which I call attention in connection with the statements in the paper as to the corrosion of salt-water piping, is the fact that this difficulty has been solved effectually on U. S. naval vessels by the use of lead-lined pipe for such purposes. This has eliminated the difficulties referred to.

Chief Constructor R. M. Watt, *Vice-President:*—As I was absent from the room when this paper was discussed, I desire to communicate the experience of the Navy Department in connection with the inference that might be drawn from the statements appearing at the bottom of page 151.

Lines of suction and discharge piping are continued through the inner bottoms of naval vessels by sea chests. Sea chests were first made of cast steel, and outboard delivery piping was made of wrought steel tubing, whereas the lines of piping were in many instances ofcopper. When sea chests were made of cast steel, a not infrequent item of repairs to naval vessels was the renewal of steel sea chests because of the corrosion and pitting at the inboard end where it was impracticable to fit zinc protectors. Accordingly, a large-scale test was determined upon, and the U. S. S. Massachusetts was selected for the purpose, inasmuch as her starboard outboard delivery tube had been renewed three times, and the port outboard delivery tube had been renewed twice in a period of commission of less than five years. The experimental substitution of composition tubes for the wrought steel tubing was ordered. Around a rectangular opening through the shell plating a reinforcing plate was fitted, to which the composition casting attached, and a zinc protector was fitted flush with the outside plating in the opening through the shell plate. When examined a year later the tubes were found to be in the same condition as when installed, the zinc showing unmistakable evidence of attack and requiring renewal. There was no pitting of the reinforcing plate and none of the outside plating, except some very slight pitting for three or four inches abaft the zinc. This pitting has been eliminated in later vessels by extending the zinc protector further abaft the opening. The results obtained were so satisfactory that all sea chests and outboard deliveries were afterwards, and are now, made of composition, and their renewal in recent years has been most infrequent.

Lieutenant-Commander Lyon (Communicated):—Having read very carefully the discussion of his paper by Naval Constructor Williams the author can only state as follows: He had no intention of placing himself in the attitude of

regarding the price of a paint as an index of its efficiency nor does he believe that a careful reading of the paper justifies such conclusion. His intent was to lay stress on the use of the proper paint for the service required of it regardless of the cost. If a cheap paint will give better service under a certain condition than a more expensive one then use it by all means, but use the proper paint under any circumstances. The author believes with the critic that the most effective paint for the purpose is the one to use, but does not agree with him in saying that a cheap paint properly compounded has of necessity greater merit than the standard paints. The author has not lost sight of the fact that zincs are put on for the purpose of protecting the steel from the electrolytic action produced by copper. He stated on page 152, top line, that in his experience zincs do not stay in the bottom below sea chest openings (these chests are of composition connected to steel), and that the corrosion around these chests is no more noticeable than that around other similar openings if the steel in the vicinity is properly painted. He knows full well that bare steel connected by good metallic contact to copper or composition will have its corrosion increased by such contact when immersed in any sea or distilled water at ordinary temperatures.

Had the constructor carried his test as that he showed for a period of thirty days, he would probably have found that, after the zinc had become covered with zinc oxide, the zinc-protected piece would have been in as bad or worse condition than the unprotected one. The author in his experiments considered this due to the fact that the zinc oxide added to the corrosive effect of the copper. A piece of zinc (rolled for boiler use) and a piece of American ingot iron, in one case, and steel, in another, connected by a copper wire, screwed hard into each, protected the iron and steel for four days; in distilled water by the end of seventeen days the protective effect of the zinc was entirely lost, and at the end of thirty days the steel and iron connected to the zinc had lost more per unit of area than similar pieces of the same irons and steels similarly connected to themselves in the same water.

If steel is galvanized in such a way that a complete coating, impervious to water, is obtained and the coating is thick enough to stand the corrosion on it as long as the ship lasts, it is a good thing to use. In the present state of galvanizing the above ideal condition is very seldom obtained. The author's chief objection to galvanized fittings and piping on board ship is that when the zinc is once gone it cannot be renewed and the ship's material is damaged more where it is gone by the presency of zinc oxide than it would have been had the zinc coating not been used.

The statement of the constructor that the difficulty due to corrosion in salt water piping on U. S. naval vessels have been solved effectually by use of lead-lined piping is seriously questioned. There is the same objection to this method as to that of galvanizing. Unless the piping in all of its parts is perfectly lined more harm than good is done the piping.

More can be done to prevent corrosion of piping by seeing that the pipes are made of good homogeneous metal, properly heat-treated in the finished product, and then properly fitted, than can ever be done by lining with lead, zinc, or lacquer.

With reference to the statement made by Chief Naval Constructor Watt the author has to say that he has served on seventeen ships in the Naval Service, on two for over three years each, and has no recollection whatever of having ever seen any trouble with the sea chests whether of steel or composition nor of the surrounding steel. It is believed that the sea chests of the Oregon, on which he served three years, were all of composition. No trouble was ever experienced with the outboard deliveries from commissioning in July, 1896, to August, 1899. It is the author's belief that the trouble on the Massachusetts must have been due to the metal used or to the way in which it was treated or fitted.

It is the author's belief that more time and money have been wasted in the U. S. Naval Service by a too quick generalization from a specific incident without proper analysis than by almost any other one cause.

THE PRESIDENT:—Is there any further discussion on this paper? In the absence of the author, we will close the discussion and proceed to the next paper, with a record of a vote of thanks to Commander Lyon. The next paper in order is No. 8, entitled, "An Electrically Propelled Fireproof Passenger Steamer," by Mr. W. T. Donnelly and Mr. G. A. Orrok, Members.

Mr. Donnelly presented the paper.

AN ELECTRICALLY PROPELLED FIREPROOF PASSENGER STEAMER.

By William T. Donnelly, Esq., and George A. Orrok, Esq., Members.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

Historically speaking, the marine transportation of passengers in power-propelled ships commenced on the Hudson River in August, 1807, with the voyage of the Clermont from New York to Albany. This vessel was 150 feet long by 13 feet beam and was propelled by an engine purchased by Robert Fulton from James Watt, and the real invention of Fulton consisted in the design and construction of the transmission machinery whereby the power of the engine was applied to paddle-wheels, one on either side of the boat. The amount of power thus applied was about 25 horse-power, and the time required to make the trip from New York to Albany with this boat was thirty-seven hours.

It is perhaps worthy of remark that to-day there are on the Hudson River passenger boats running from New York to Albany 384 feet in length and using approximately 6,000 horse-power, making the run of 140 miles from New York to Albany in nine hours and carrying 5,500 passengers. This is the greatest number of passengers that can be carried on any vessel in the world, and it is not too much to state that these boats represent the very last word and the highest skill in naval architecture to which man has attained.

Having made this contrast so creditable to American invention and skill, it is desirable to make another for which no credit can be claimed. Within twenty-five years after the construction of the steamer Clermont, there was fully developed the American type of walking beam engine, comprising a single low-pressure steam cylinder, a connecting rod, walking beam and pitman operating a crank-shaft across the boat with paddle-wheels on either end. Steam was furnished by low-pressure boilers at approximately 30 pounds per square inch and delivered from the cylinder to a surface condenser, the air pump for which was operated from the walking beam of the main engine. Strange as it may seem, in one particular class of service this engine has persisted practically without modification to the present day. We refer to the class of steamers used for the short summer season, exclusively for carrying passengers and known as excursion boats.

There are in this harbor, at the present time, twelve or fifteen steamers of this class which are from thirty-five to fifty years old. The largest and

most representative boat, the steamer Grand Republic, was built in 1878; the engine in use on this boat was then taken from another boat, and, while its origin is now uncertain, it is believed to be between fifty and sixty years old. This engine has a cylinder 72 inches in diameter by 12 feet stroke and makes between 16 and 17 revolutions per minute, with 30 pounds steam pressure and a vacuum of 26 inches, developing approximately 1,400 horse-power.

Up to about 1878 the hulls of all excursion and river passenger boats were of wood, but from that time on hulls have been built of steel. Very few have double bottoms or any considerable division of hull by watertight bulkheads, and the superstructures at the present time are of the very lighest wooden construction.

In other words, while we have made such tremendous advances in all structures on land regarding safety appliances and fireproof features, the excursion passenger steamers upon which during the summer months we send away our women and children have been allowed to remain at a standard of almost one hundred years ago.

The object of the paper here presented is not only to bring these existing conditions to your attention, but to point out how this class of vessels can and should be brought up to the standards of the present engineering practice as regards propelling power, the construction of the hull, and the fireproofing of the superstructure.

Regarding the dangers of fire upon water there is little or no necessity for enlarging, as the records of loss of life and property from this cause are conclusive, and it is almost beyond comprehension why the problem has not received more careful consideration long before this.

The plans herewith submitted show a vessel of approximately the same over-all dimensions and passenger capacity as the steamer Grand Republic, so well known for the last twenty-five or thirty years to the summer traveling public. The hull of the vessel here shown is 275 feet long over all, 260 feet on the water-line with an extreme beam of 68 feet and a moulded breadth at the water-line of 45 feet 8 inches, and is designed to have a displacement of 1,714 tons on a draught of 10 feet. The hull is designed to have a double bottom for a length of 188 feet and double sides carried up to the deck for a length of 109 feet, corresponding to the machinery and boiler space. It is also intended to make the coal bunker space on each side of the boilers with semi-watertight doors, which will add a large additional factor of safety. The design provides for seven watertight bulkheads carried up to the deck and there is no provision for openings; that is, so-called watertight doors through bulkheads are to be entirely eliminated.

By referring to the general design elevation it will be seen that the vessel is to have three full decks and that the pilot-house and officers' quarters comprise a fourth.

The propelling device or paddles of the Grand Republic are 38 feet in diameter by about 14 feet face and occupy a space extending through three decks on each side of the boat of about 40 feet by 16 feet. The plan here submitted makes this additional space available for passengers and also makes a much superior interior arrangement possible.

The boiler space is divided by watertight bulkheads into two fire-rooms and the boiler casing is carried up through the center of the superstructure. The engine-room space is also surrounded by steel housing in such a way as to prevent the possibility of steam escaping into the passenger space.

The superstructure and decks are to be built entirely of light steel, no wood being used except as a guard strip on the outside, and with this construction it will be practically impossible to start or maintain a fire in any part of the boat.

The matter of fire risk on passenger steamers has been previously discussed in this Society. At that time it was contended by some of our members that the combustible nature of cargo would always prevent the possibility of fireproof construction. In this connection we wish to point out that the class of steamers herein referred to carries no cargo whatever and that there is not the slightest practical or engineering difficulty in making the construction such that the creation or maintenance of a dangerous fire will be impossible.

Attention is called to the detailed design for the steel deck in which very light plates are used running across the vessel, with their edges flanged and united to steel carlins. The upper surface of the plating is to be covered with canvas which makes a watertight and weather-proof joint where the plates meet. The carlins are to be supported by 6-inch steel I-beam stringers carried on steel pipe stanchions. It should be here mentioned that these steel-pipe stanchions and steel stringers under carlins are now in use on the highest class of river passenger boats.

Regarding the turbine electric power generating plant and the adaptation of electric motors for the propulsion of this steamer, it is very apparent that this marks but the beginning of the broadest application of electricity to marine transportation. It took from 1765, when the steam-engine was perfected by James Watt, to 1807 to adapt it to the propulsion of ships, and it is not in any way surprising that it has taken from 1876, about the time of the invention of power transmission by electricity, to 1912 to realize the possibilities of its application to marine propulsion.

Up to the time of the invention of the electric generator and the electric motor, it was generally considered that the development and use of power was a single function; that is, that anyone desiring to use power must create it for himself. With the advent of electricity, it became manifest that the creation and use of power was something which could be divided, and it at once became apparent that, while everyone wanted to use power, very few people wanted to create it, and consequently there has grown up in recent years a new industry of tremendous importance for the creation, distribution and sale of power.

Bearing this in mind and applying it to marine transportation, we find that up to the present time it has been firmly fixed in the minds of all that power for the propulsion of ships must be created, controlled and applied by one set of men, but we now wish to point out to you and forcibly call to your attention the fact that a tremendous advantage can be gained by separating the generation and the use of power for the propulsion of vessels; that is, it is becoming more and more apparent that the steam turbine is to stand in a class alone as regards simplicity, reliability and economy for the production of electric energy, and it may be said without any possibility of contradiction that no device has been, and in all probability never will be invented, combining so many desirable qualities in the matter of application of power as the electric motor.

The electric motor has no relatively moving parts; that is, a single, solid, rugged metal structure known as an armature or rotor revolves supported in two bearings which receive a pressure due only to the weight of the armature, no matter what power is being transmitted. For controlling the speed and reversing the direction of this motor no complication whatever is involved and no additional moving parts are required.

You are requested to compare this statement with the modern steam marine engine so familiar to you all that no description is required. There is in fact no comparison whatever. It is well known to you that after each voyage the steam-engine requires to be jacked up and all the bearings and running parts overhauled, and it is certain that there is a very large source of economy in the saving of the lubrication of steam cylinders, let alone the large consumption of oil by all the working parts of a reciprocating marine engine.

At the present time all steam-engines are controlled by the engineering staff through signals from the pilot-house. In the case of the electrically propelled steam vessel this double control, involving a signal between two parties, will be eliminated, the operating staff would deal solely with the production of the power, and the use and control of the power would be centered

in the hands of the executive officers of the ship, as it clearly should be. To this division of responsibility electricity lends itself in a marvelous way.

We are well aware that marine authorities have questioned the reliability of the control of the propelling power from a distance, but this, scientifically and practically, has long passed beyond the matter of argument. To give an illustration familiar to everyone, reference is made to the subway trains in which motors coupled to ten separate cars distributed throughout a train and aggregating a very large horse-power are handled from one point, being started, stopped and reversed, working in unison and with much greater reliability than has ever been attained between the pilot-house of a steamship and the engine-room.

It should further be stated that every part of the power plant—that is, for the production, utilization and control of the power—is of standard manufacture, and that, in the control of the motors, exactly the same appliances will be used as are now in use to control railway motors.

Granting the broad application of electric generation and propulsion to steamships, we have before us new conditions altogether unexpected and surprising. In the Grand Republic, the steamer in comparison with which the plans herewith are submitted, we have a vessel in use for not more than four months in the year. For the remaining eight months we have an investment totally incapable of any use. In the power plant of the steamer here shown, we have a generating plant of 3,000 horse-power which can deliver itself to any location on navigable water and deliver 3,000 horse-power in electric energy utilizable for any possible purpose, either for light or power, and if this system were to be applied to a freight steamer, it is equally apparent that instead of the power plant of the steamer being useless when in port, all the power would be available for handling cargo or for any other purpose.

From the propelling of individual boats by means of electricity generated on them, it is only one step further to provide a vessel not only generating electric power for its own propulsion but also for the propulsion of other vessels, and while it is not intended to take up this matter in this paper, those interested in the general subject of power as applied to marine transportation are referred to a paper published in International Marine Engineering under date of January and February, 1908.

The design of the machinery for the vessel whose plans are here presented has been treated from the viewpoint of the central station, the control of the motors driving the three shafts being in the pilot-house, making the load on the leads to the motors (corresponding to the load on the feeders) as independent of the generating apparatus as in a power station. The

generating units are standard pieces of apparatus, generously proportioned for continuous service, which have been developed to meet the exacting conditions of central station lighting service. They are provided with an automatic oiling and water-cooling system and the various attachments which have been proved necessary to insure the required regularity of operation.

The two units, 1,500 kilowatts, 80 per cent power factor, maximum rating, are located side by side on a specially constructed portion of the main deck in a glass enclosure where suitable ventilation may easily be secured for the generators. Each turbine has an exciter direct connected on the main shaft and the exciter regulation is automatic in its character, only requiring attention during the starting and stopping of the unit. One 25-kilowatt, steam-turbine-driven, independent exciter is also installed for starting up and to furnish lighting for such times as the main units are not in operation.

Directly below the turbines are the condensers, each of 3,000 square feet surface, with the other necessary auxiliaries, feed pumps, bilge and fire pumps, etc. The condensers are proportioned to maintain a 28-inch vacuum with the 70-degree water prevailing under summer conditions in New York Harbor. The circulating pumps are turbine driven and under normal conditions will deliver 5,000 gallons per minute through the condensers.

The hot-well pumps are on the same shaft as the circulating pumps and have a capacity of 150 gallons per minute against a head of 50 feet. These two pumps are of the centrifugal type and of standard design. In the wings on either side of the condensers are the two air compressors which are also used for air pumps and will, by a special device, discharge either at atmospheric pressure or at 10 pounds gauge. Either unit, as an air pump, has a capacity sufficient to handle both condensers, and the air suction pipes are interconnected.

The two turbine-driven centrifugal feed-pumps are also located in the wings. Each pump has a capacity of 200 gallons of water per minute against a head of 700 feet, and one unit will be sufficient to feed the boilers except on special occasions. These pumps are run under nearly constant speed conditions and are provided with an unloading device which bypasses the feed-water should the feed-valves be entirely shut.

Two bilge and fire pumps are also provided, each of 150 gallons capacity and a fresh water tank pump of 50 gallons capacity for the make-up feed from the tanks. Above the feed pumps two open heaters, each of a capacity of 50,000 pounds of water per hour, serve to heat the feed water by mixing

with the exhaust steam from the auxiliaries. The turbine-driven auxiliaries have been proportioned to furnish about 90 per cent of the steam required to heat the feed water to 208° F. and a live steam connection will be provided for the additional heat should its use be desirable. Suitable atmospheric exhaust connections and valves are provided, and the auxiliary exhaust has an oil separator in front of each heater, although but little oily steam will be present as most of the auxiliaries are turbine driven. All of the small turbine bearings are ring-oiled and will require very little attention.

Immediately astern of the condensers and auxiliaries are the three 1,000 horse-power induction motors and the thrust bearings. These motors are very generously proportioned. They have 24 poles and a normal speed of 300 revolutions per minute. They are provided with collector rings and are controlled by means of varying the external resistance. The motors and generators are so designed that the current under a dead short circuit does not exceed two and one-half times full load current.

The controllers for the three motors are in the pilot-house and are fitted with interlocking devices as well as an automatic timing device. All the motors may be started, brought to any speed up to full speed, reversed or stopped by the manipulation of the three controller handles, one for each motor. In addition, signalling devices are installed in both engine-room and boiler-room as well as the usual bell and speaking tubes.

The fire-rooms, two in number, each containing four water-tube boilers in two batteries, are located forward of the machinery space. The coal bunkers are in the wings on either side of the batteries. Each boiler has 1,635 square feet of heating surface and 44 square feet of grate surface. The steam pressure will be 250 pounds gauge and the steam will be moderately superheated. The steam main is in duplicate with cross connections, as is the feed-water main, and both are of the highest grade. The steam piping is of steel pipe with Van Stone joints, steel flanges, fittings and valves. The feed piping is brass with brass valves and fittings. All boiler connections have two valves between the boiler and the pressure main, and the automatic stop-check valves usual in the best power-house practice will be installed. Each boiler is provided with steel, extra heavy safety valves of navy pattern.

The boilers are served by three stacks, one for the forward pair, a large one for the middle four boilers, and one for the after pair. These stacks are 6 feet 6 inches and 8 feet in diameter and 72 feet above the grates. Forced draft has been provided for, but the machinery will not be installed.

LIST OF MACHINERY.

	Weight in tons.
Eight water-tube boilers:—	
Grate surface, 44 sq. ft. each.....352 sq. ft. total Heating surface, 1,635 sq. ft. each...13,080 sq. ft. total Pressure.....250 lbs.	105.0
Main generating units:—	
Two 3-phase, 60-cycle, 1,500 K. W. maximum 24-hour rating, 35° C. rise, 3,600 R. P. M., 2,200 volts, 80 per cent power factor.....	57.5
Three 1,000-horse-power induction motors, 24 pole, 300 R. P. M.....	33.5
Three sets of switches and controllers.....	20.5
Two condensers, 3,000 sq. ft. cooling surface each Two combination turbine-driven centrifugal pumps.....	25.0
Two independent exciter sets.....	3.0
Two turbine-driven centrifugal feed pumps, 200 gallons each.....	2.0
Two bilge and fire pumps, 150 gallons Two tank pumps, 50 gallons.....	1.5
Two air compressors for 10 lbs. pressure.....	4.0
Steam and other piping.....	5.0
Two open heaters, 50,000 lbs. per hour.....	2.0
Three propeller shafts.....	11.5
Three propellers.....	3.0
Steel foundation for supporting machinery.....	25.0
Total weight of machinery.....	298.5

All auxiliary machinery is in duplicate and, as far as possible, turbine-driven units are used.

The total weight of the machinery, including propellers, shafting, auxiliaries, switchboard, boilers, piping and water in boilers and condensers will probably not exceed 300 tons. This figure includes the steel seatings for the generating units and motors. Considering an equivalent of over 3,000 indicated horse-power in the motors, the weight of machinery is approximately .1 ton per indicated horse-power.

Reference has already been made to the saving in deck space, about 4,000 square feet, by the substitution of screw propulsion for paddle-wheels. The saving in weight over the vertical beam engine type with return tubular boilers is much more marked, as the average of a number of these boats

gives for the machinery weights a figure of between .20 and .25 tons per indicated horse-power.

The coal consumption of vessels of the type of the Grand Republic is not far from 3.25 pounds per indicated horse-power under test conditions. With the ordinary running it would necessarily be larger. The vessel here described should, under test, give results approaching 1.5 pounds of coal per indicated horse-power hour, and under ordinary operating conditions the saving in coal alone would probably amount to about 2 pounds per indicated horse-power hour.

Allowing steaming thime of ten hours at full power per day for one hundred days, corresponding to the summer excursion season, the saving in coal would amount to 3,000 tons, which at $3 per ton would mean a saving of $9,000, and this amount capitalized at 10 per cent would warrant an additional investment of $90,000, which, it is believed, would more than cover the difference between the cost of the present type of boat and the one here presented.

Besides this saving in fuel there would be an additional economy in the matter of oil and general maintenance charges incidental to operating marine engines.

DISCUSSION.

Mr. Andrew Fletcher, *Member of Council:*—We all should thank Mr. Donnelly for his progressive thought and the time that he has put on this paper. But this is not, however, an entirely new subject. It has been under thought for some time, and the nearest approach to an electrically propelled vessel of any large power is the Jupiter that is yet to be tried.

It seems to me that Mr. Donnelly, in what he has just stated as to the coal per horse-power per hour, is basing his cost of power entirely on land practice, and when that power is applied to revolve three screws on a boat as described in his paper, I do not believe the electrical propulsion will work out, economically and commercially, as well as a much simpler installation of motive power, and it will take more power per ton of displacement to drive this excursion boat than if it had well-designed feathering paddle-wheels.

Mr. Donnelly has particularly spoken of the excursion class of steamers, and made a slap at the old beam engine, stating that there has not been any advance since twenty-five years after the Clermont was built; in other words, that the engine

was fully developed about twenty-five years after the Clermont came out. Our concern, during the past sixty years, has probably built more beam engines than any other concern in the United States, and possibly, I might say, almost more than all the other concerns together; and we have built not only the simple beam engines, but also a number of compound beam engines, the largest compound beam engine being that in the Fall River Line steamer Puritan, having a low-pressure cylinder 110 inches in diameter by a stroke of 14 feet of piston. The celebrated steamers, City of Erie and the City of Buffalo, have also compound beam engines. So that in criticizing some of the statements that Mr. Donnelly has made, and desiring to do it in a conservative way, I feel that so much has been said about the old-time beam engine by those who only have a superficial knowledge of its worth for particular services, that once in a while we have to get back at them.

Mr. Donnelly has made reference to the weight per horse-power. His figures are anywhere from 25 to 35 per cent out. He has spoken of the economy of the beam engine in comparison with his electrically propelled excursion steamer, and there I know he is fully 20 per cent out, conservatively, so that his paper to my mind loses a lot of its value, except as to the progressive thought that is contained therein.

He starts off in his paper by making a comparison with the old Grand Republic, one of the very oldest boats in the harbor. He states himself that he does not know when the engine was built, that it was built many, many years ago, before it was installed in the Grand Republic, and has been in the Grand Republic since 1878. It seems to me that is a good record, for it is still going along, and I might say only yesterday the owners of the boat asked us to make some repairs on this old engine preparing for next season's work. But he takes a type of an old beam engine, with a piston speed working, as he said, about 400 feet per minute. He pays absolutely no attention to the modern short-service excursion boat, fitted with a walking beam engine, where the piston speed in some cases is over 600 feet per minute, and, as you know, taking the same sized cylinder, you can obtain very much more power by increasing the pressure and piston speed. Here is an engine, for instance, with a 72-inch-diameter cylinder and a 12-foot stroke of piston, making sixteen revolutions per minute. We have vessels on the Hudson River with approximately the same sized cylinders running from 28 to 29 or 30 revolutions per minute, as in the case of the latest Hudson River day excursion steamer Robert Fulton, and also in the case of the steamer Albany of the Hudson River Day Line. So that to compare a modern beam engine, with a 72-inch cylinder, as he has expressed it here, with the Grand Republic, is absurd, that is, from the point of view of the builder of beam engines. He also does not state the advance which has been made in the paddle-wheels. He takes that old boat, with the old-style, less efficient water wheel of the fixed bucket type, and makes his comparison. This engine that he speaks of has wheels 38 feet in diameter. We would not think of putting in wheels like that to-day, and have not for years. For that size of engine, if we wanted to run at double the speed, and which we can do very easily and economically and safely, we would put in wheels with the feathering type of buckets fully 8 to 11 feet smaller in diameter,

depending on the character and service desired, so that when you consider these facts the paper loses much of its effect with me, because I know in that first statement he makes, as to the development, he has not thoroughly familiarized himself with facts. I would not have you feel that I think the beam engines are the only engines for these boats, but it always has been our idea, and I know that the idea is shared by a large number of owners of excursion steamers who look for dividends, and especially where the route is short, for say river and harbor work, that the beam engine supplies largely the requirements. These owners want a machine just as simple as they can get it, many of them must consider the first cost, the cost of operation and the cost of maintenance, and the simpler you can have a steamer's machinery, especially for short service, the better it is, for coal per indicated horse-power per hour is not the only consideration.

I would not have you think that we are purely beam-engine men, because, as most of you know, we produced the first Parsons marine turbine ship that was built in the United States, the Governor Cobb, and followed it with the turbiners Yale and Harvard, and have built all kinds of marine engines, from the four-cylinder triple-expansion screw engines to the four-cylinder double-inclined triple-expansion engine-driving, feathering paddle-wheels, as in the case of the Fall River Line steamer Plymouth, and the four-cylinder double-inclined compound engines, like in the Fall River liner Priscilla, an engine of about 9,000 horse-power, and then when you come to the Hudson River paddle-steamer Hendrick Hudson, and the new paddle-wheel boat we are now building, the Washington Irving, for the Hudson River, with approximately 7,000 horse-power, and using a three-cylinder compound engine of the nclined type, you ca n see that our experience has covered quite a range. So that I feel that the various types of engines have their particular places, and where a beam engine for one service would be suitable, in another place it would be absolute folly to use it, and so it goes, down through the list of the various kinds of engines.

A reference was made in this paper, I think, as to the more or less flimsy character of the present excursion boats. We will find in the modern excursion boats that really in the past ten or fifteen years there have been many refinements introduced in their construction; for instance, both the machinery and the boilers are enclosed in steel all the way up. Steel girders are used in lieu of wooden girders, there are practically no wooden stanchions used, steel stanchions are used; and when it comes to the state-room boats, considerable advance has been made in them, and they have tried to fireproof them as much as practicable. We know that the substitution of composite board and of the so-called "never-split" panels is far safer than the pine panels formerly used, which were much heavier and would ignite more quickly, and their adoption has been quite a great advancement in the line of safety. The Fall River Line, of which there are representatives here, has given the fireproofing of a boat a great deal of thought and has made progress in that direction. We all wish to be progressive and do all we possibly can to insure the safety of the passengers. However, the commercial end must be looked after, that is, the financial return to the steamboat owner, and it would seem to me, in this

vessel that Mr. Donnelly suggests, the expense of construction would be so great, I do not know of any excursion steamboat company around the harbor of New York, or in any other harbor of the United States that we have had business dealings with, that would consider its construction for their service.

There have been steel superstructures built. A boat was built that ran between Norfolk and Washington, and had a superstructure entirely made of steel. I do not think that boat has ever been duplicated. The Pennsylvania Railroad Company a few years ago had built for them a steel superstructure single-deck ferryboat that now runs from Camden to Philadelphia, and which was built by the New York Shipbuilding Company. It has given very good service, but in this latter case the superstructure is infinitely less than it would be on an excursion steamer with its numerous decks. While we should do everything that we possibly can to preserve life and insure the safety of the traveling public, the safety and lives of our women and children, as Mr. Donnelly states, yet we must be practical in it, and I think without doubt in the case of the steel superstructures, with the atmospheric conditions that exist on salt water service, that the preservation of such a mass of metal superstructure would be quite a problem to take care of, with the greater or less amount of vibration, even though you used turbine or triple screws, as Mr. Donnelly states.

He makes reference here also in a general clause to the great loss of life. One life lost is a frightful thing. I telephoned yesterday to the people who operate this old excursion steamer Grand Republic, and also the greatest fleet of excursion boats in the harbor, the Iron Steamboat Company, with boats running to Coney Island, and asked if they had any data as to the amount of passengers carried, and the percentage of lives lost. Mr. Bishop, the president of that company, sent me a very long letter yesterday which is full of statistics, but I will only give you a few of the interesting things he has compiled. These are facts he states, and are on record with the Supervisor Inspector of Steam Vessels, and I do not doubt his statements are correct. The following is from the annual report of the Supervisor Inspector General of Steamboats, an absolute record.

Going over a period from 1900 to 1910 inclusive, the records in the Supervisor Inspector's office for the United States show that during the period mentioned 3,730,616,083 passengers were carried, and the loss of life, from all causes, of every character, accidents, fire, collisions, everything else——

THE PRESIDENT:—Suicides?

MR. FLETCHER:—Everything imaginable, Mr. President—was one life in 735,822 passengers carried; and for the Second District, which comprises the harbors of New York, Boston, Philadelphia, New London, Albany, Portland, Providence, Bangor, Maine, New Haven, Conn., for that period from 1900 to 1910 inclusive—and this district and its report take in the frightful loss of life in the case of the General Slocum, and also the loss of life due to the sinking of the Larchmont in Long

Island Sound, which you may remember was struck by a schooner—in that district the government records show that over 2,960,432,640 passengers were carried, and the loss of life, including these dreadful casualties, from all causes in that district in that period, was one in 1,611,998 passengers carried, and for accidents one in 1,905,857 carried. So it seems to me, gentlemen, notwithstanding our old excursion steamers, the government records of these various ports, taking our own port where there is a tremendous excursion business done, it a remarkable record for the old present-day excursion steamers.

Mr. Bishop's own company, the Iron Steamboat Company, in the thirty seasons that they have run their vessels, have carried over sixty million of passengers. This company, I may say, operates the Grand Republic referred to in Mr. Donnelly's paper. Mr. Bishop states: "In thirty seasons we have carried over 60,000,000 passengers between terminal points without the loss of one life, and this in view of the fact that in the season of 1911 alone the steamers made 2,974 trips between Coney Island and New York, 328 trips between Rockaway Beach and New York, 178 trips between New York and various groves with chartered parties and special excursionists, and about 250 trips to the fishing banks."

There are, no doubt, excursion boats in the harbor that should be rebuilt or replaced, but, nevertheless, the government records we cannot go back of. Some frightful accident may happen next year or at any time.

I believe the safety of passengers, provided the vessel fully complies with our Government Steamboat Inspection Rules, largely depends upon well-organized and efficient crews managing the vessels.

(Vice-President W. L. Capps in the chair.)

Mr. Warren T. Berry, *Member:*—While I admire the Hudson River passenger boats and have the greatest respect for their designers, I do not think they represent the highest skill in naval architecture to which man has attained. Many of our lake, river and sound steamers which provide hotel accommodation, to say nothing of battleships, and vessels like the Lusitania and others, certainly represent infinitely more skill on the part of the designers.

Regarding the necessity for fireproof steamers the authors state that it is "almost beyond comprehension why the problem has not received more careful consideration long before this."

If they will refer to the Proceedings of this Society for 1906, Volume XIV, pages 1 to 29, on "The Construction of a Fireproof Excursion Steamer," by Mr. Wm. Gatewood, and "A Fireproof Ferryboat," by Mr. F. L. DuBosque, and the ensuing discussion, I think they will admit that the problem received considerable, careful attention and consideration at that time, and I fail to find that the present paper overcomes many of the difficulties of fireproof construction advanced then, such as the discomfort to passengers and crew from heat in the summer in structures entirely of steel; the objectionable springiness of light steel decks; the additional weight and cost of

steel upper works; and the troubles in connection with compass adjustment in such a structure.

The present paper contemplates a vessel of approximately the same length and beam as the steamer Grand Republic. The Grand Republic's boilers have 180 square feet of grate surface and the design in discussion specifies nearly double this surface, or 352 square feet. Assuming vessels of the same size as to carrying capacity, will not the coal consumption be tremendously increased notwithstanding the reduction in consumption per horse-power assumed in the paper?

Cheap transportation by trolley has reduced most of the excursion business in this port, at least, to a very low standard of cost, and it is doubtful that any material increase in the cost of operation or maintenance could be justified. If the vessel is uncomfortable or the price of transportation has to be increased to meet the requirements of larger coal bills, maintenance and general charges, the steamer is not commercially practical.

The double hull construction shown in the midship section provides 16 inches clear space between outer and inner hulls at the side. How can this space be properly inspected, cleaned, and painted, or otherwise cared for?

It would be interesting to know the weights of the upper steel structure described in this paper. The increase in horse-power from 1,400 on the Grand Republic to 3,000 seems to be considerable for a vessel of the same size and service.

The beam engines referred to at least seem to have the peculiar advantage of durability, and any one who has had experience in their operation can testify to their remarkably low cost for maintenance.

Mr. Wm. H. Fletcher, *Member*:—There are one or two points I would like to touch on to which neither of the previous speakers have referred. Mr. Donnelly is right in assuming that it is up to the naval architect and the builders to do everything possible to conserve the safety of passengers traveling on steamers. We all realize that we are in a progressive age, and while some have not progressed as fast as others, those of us who may be a little backward feel that if we do progress it must be in a manner that is consistent with commercial conditions. In other words, the naval architect should not advise, nor the builder undertake to construct a vessel which, due to excessive cost, will not be a commercial success when finished. If we could manufacture vessels, then I believe metallic joiner work would be made at a cost that would not be prohibitive and could then be used commercially. Those of us who are in the business of building passenger steamers find that one of the most serious troubles we have to contend with to-day is the greatly increased cost of production, which in some cases is almost prohibitive.

In designing and constructing a vessel, all concerned should consider the character of the business and the possible earning capacity of the vessel on the particular route for which she is ntended, and in determining the character of power to be used, should select that which lends itself best, all things considered, to the conditions there existing, rather than be governed by purely theoretical considerations.

We have found in many cases that the beam-engine paddle-boat is best suited, and I will request President Taylor to tell you of a comparison that he made some syears ago between the twin-screw triple-expansion steamer Sandy Hook or Monmouth and the Hudson River Day Line steamer New York, a single-cylinder beam-engine boat.

I do not think Mr. Donnelly is quite fair, either to the designers, the builders, or the public, in selecting the steamer Grand Republic as a typical passenger excursion boat of the type in use to-day. She is a very old wooden boat, very few of which, if any, are now built, her boilers are down in the hold and are surrounded everywhere by wood-work, and there is always a greater possibility of fire under such conditions. The modern passenger boats are almost universally built of steel, a steel deck is placed over the boilers, even if it is not for the entire length of the vessel, and the boilers and machinery are encased in a heavy steel casing, which runs from the main deck up through and above the topmost deck, thus encasing the boiler and machinery entirely in steel and minimizing the danger of fire from same. That we might reasonably consider a step in the advance of progression, as it greatly reduces the chance of fire.

Electricity, of course, is another element that had added to the safety of modern boats with their great wooden superstructure.

The records which Mr. Andrew Fletcher has just read, and which records are a statement of facts, show that the danger of the traveling public is to-day very small, and we are apparently safer on the present passenger steamers than we would be in our own homes, and we might almost include the fireproof building. To my mind there is no place wherein we run a greater risk of danger from fire than we do in the modern American basement or other three, four or five-story private house, such as we have particularly in the city of New York. I think you will find, if the records are searched, that the loss of life due to fires in private residences, when they do occur, and I refer to the residences of people of means, is far greater in proportion to the number of people involved than even on the old wooden steamboats. I must, however, agree that these large boats with their immense superstructure entirely of wood do look dangerous, and I have often looked at boats of this character and wondered what would happen if a fire really got started. We, of course, had an illustration in the case of the General Slocum. I happen to know about that particular vessel, and I think she burned a little more rapidly than most wooden boats, from the fact that when she first came out, her entire joiner work, instead of being painted, was shellacked and varnished, and then year after year shellac and varnish were added, and finally, after many years, she was painted. This boat was a great open-deck structure, intended for carrying passengers during the summer months, and was very much like a large loft building, in which there were no partitions. The hull of the boat was of wood and there was every chance for the flame to make great headway with very little hope of stopping a conflagration, should the fire once get well started.

In the Sound and Hudson River night boats there are thermostats placed in

each state-room, which in turn are connected with an annunciator in the office, indicating at once if there is a fire, and just where the fire is located. One of the greatest dangers on boats of this character is from a drunken or careless passenger lighting matches in his state-room for the purpose of smoking, and igniting the bedding in his berth.

All the various improvements which are designed for the safety of the traveling public add to the cost of the vessel. This, with the increased cost of some of the materials used, as well as the shorter hours and the increased pay of labor, put both the designer and builder up against a rather serious problem in their particular march of progression, as we to-day are endeavoring to build ships cheaper by increasing the wages and shortening the hours, this method being practically forced upon us by our government making it obligatory in the yards where naval vessels are built to work eight hours, and as the larger portion of shipbuilding to-day is for the government, it is practically forcing the yards to an eight-hour day, without any decrease in pay. When we add to this the additional cost of the various improvements, which have been introduced, both for the safety and comfort of the traveling public, and we realize that the tendency of the demand of said public is for a decrease rather than for an increase in the cost of transportation, one can easily understand how impossible it is for either the designer or the builder, in considering any particular proposition, to lose sight of the practical and commercial elements which are involved, and which must be considered in any proposition.

I might add, in regard to the question of economy, I am sure Mr. Andrew Fletcher did not, nor do I, mean to imply that the beam engine is the most economical power you can install in a boat, but in many cases it is most desirable, when all conditions entering into the proposition are considered. In my opinion, your three-screw propulsion on the Hudson River or other comparatively shallow waters will not return anything like the proportion for the power expended you would obtain out of a well-designed, feathering, side-wheel boat, because of the fact that the side wheels seem to be the ideal method of propulsion under conditions of this kind; whether you use a beam engine or become more progressive and use a three-cylinder, compound inclined engine, operating under a higher pressure, is a matter which must be considered entirely from the standpoint of one's pocket-book. If one wants refinements and is willing to pay for them, there is no reason why one should not have them, and most builders are both willing and glad to furnish the refinements, if so desired.

Many years ago when either the Sandy Hook or the Monmouth (I forget which) first came out, there was considerable discussion as to the relative speed of this vessel and that of the Hudson River Day Line steamer New York. Our president, Mr. Stevenson Taylor, was at that time a member of our concern and naturally took a very deep interest in the subject. We then felt, and do to-day, that vessels like the New York and Albany compared with vessels like the Sandy Hook and Monmouth, both carrying passengers only, at about the same speed, that is, approximately 19 miles an hour and running in comparatively shoal waters, that the

advantage, if any, was and is in favor of boats of the type of the steamer New York, in that they carry their passengers more comfortably and, all things considered, at as little cost, although on the one hand we have a triple-expansion twin-screw vessel and on the other a single-cylinder surface condensing beam engine with feathering wheels. An actual comparison was made from the books of both companies as to the cost of maintenance and operation, but only in regard to the propulsive power itself, but as Mr. Taylor, who personally handled this entire matter, is here, he can tell you better than I just what was found.

I would suggest to Mr. Donnelly that if we desire to progress to the limit in the matter of safety, why put in boilers at all, or have any fire on the vessel? Why not institute, say three Diesel engines, and be without fire? Personally I see no reason why architects and builders should approach this question of fighting fire on board a boat in any different manner than that which we would meet this same question in our own homes. We should and must consider the cost in applying our refinements, but above all, take every possible precaution to prevent a fire from gaining headway. In my opinion, had the General Slocum been tied up alongside of a dock in the city of New York, with all its fire-fighting facilities, both on land and by water, and the fire started, the loss of life would have been almost as great as it was with the boat out in the river.

Mr. George W. Dickie, *Vice-President:*—I am going to say one or two words, because when I read this paper I got quite a shock. Apparently I had been boasting for a good many years about something that was not so. I thought when I was an apprentice that I had worked on the first, or about the first surface condensing engine for a steamboat that had been built, and I am not near old enough to have done that, if the statement in the paper is true, that the surface condenser was brought into service twenty-five years after the date of the Clermont. The Clermont was launched in 1807, and twenty-five years later than that would bring us down to 1832, which was just thirty years before the time when I worked on what I thought was about the first surface condenser for a steamboat that had been made.

I think this is a good paper to bring before this Society, because it is one of the kind that opens up the way to a lot of discussion, like the challenging of statements which have been made here, and I think it is a good thing to have a paper that is full of that sort of thing, because otherwise we would not have heard anything about the things we heard about to-day. Some ten years ago I took a trip on a very fast passenger steamer, the Columbia, from Glasgow to Iona, this steamer making 24 miles an hour, was a side-wheel steamer, feathering wheels, engines making 44 revolutions per minute, oscillating 3-cylinder compound, two low pressure and one high pressure in the center. It was one of the most admirable pieces of engineering work I had ever seen. I made strict inquiries as to the consumption of fuel, and was told that it was 2.1 pounds per indicated horse-power per hour, and I think it is very unfortunate that comparisons should be made in a paper like this, taking something that is exceedingly old and amongst the first attempts to do any-

thing really in that line of engineering, and comparing that with the very latest modern practice. I doubt, however, whether a three-shaft vessel operated second hand from a generator would equal the consumption I have just mentioned for the direct-acting oscillating engine. You know in Scotland the oscillating engine with the side-wheel steamer has the place that the beam engine has here, and they have both been developed along that line to a remarkable degree of efficiency. I simply mention this one fact about the condenser, and that is what brought me up, and while I am on my feet I desire to say that it is a matter of pleasure to me to meet you gentlemen, whom I have not seen for a long time.

Mr. Charles M. Englis, *Member:*—I would like to make a few remarks in relation to this paper, inasmuch as I was one of the builders of the steamer Grand Republic, and therefore ought to know something about it. The paper states, referring to the engine used in the Grand Republic, "while its origin is now uncertain, it is believed to be between fifty and sixty years old." I would like to inform Mr. Donnelly that that engine came from the steamship Morro Castle, which was built about 1860, was removed from S. S. Morro Castle in 1877 and placed in the ship Grand Republic in 1878, and to-day the company owning the Grand Republic are nursing the engines preparatory to putting in new "gallows frame" and "engine keelsons," and no doubt it could go on for fifty years longer.

Further than that, I would say, in regard to expense, Mr. Donnelly does not tell us what the ship designed by him is going to cost. I am afraid that the cost would be such that the men in the excursion business in this port of New York would find it absolutely prohibitive. The excursion business is of short duration, and a very costly boat would not be profitable in that service.

The history of the steamboats Grand Republic and Columbia is as follows: The boats cost, at the time they were built, less than $100,000 each, engines, boilers, and all the outfit complete. Mr. R. Cornell White managed and ran these boats for two years, when he failed. They were then sold and brought $70,000 each. The company which bought them and ran them for a time could not earn any money with them and they were sold, one to the Baltimore & Ohio Railroad for $60,000, and the other, the Grand Republic, to another company which operated it, for $60,000, and these same people also owned the General Slocum. The Grand Republic was then sold to the people who now own her for less than $30,000, and they are the only people who have made any money on her. The Columbia was the boat which was sold to the Baltimore & Ohio Railroad.

I do not see where you can add $90,000 to the cost of any vessel, and get that money back, or anywhere near get it back. Much emphasis is laid in the report regarding the loss of life by fire. I made the remark to a gentleman sitting near me that I have been in the business for many years, and know of but two cases of loss of life by fire on board a steamer; one was the General Slocum and the other was the Seawanaka.

The paper states that wooden vessels were not built after 1878. I would like

to disagree with that, because I built the steamer Adirondack in 1895, some years after 1878; also several steamers between the dates mentioned were constructed of wood. We gave up the use of wood finally, not because we objected so much to the wood, as to the fact that we could not get the wood in proper sizes and we had to go to steel. Mr. Donnelly says in the paper: "Attention is called to the detailed design for the steel decks in which very light plates are used running across the vessel, with their edges flanged and united to steel carlins. The upper surface of the plating is to be covered with canvas which makes a watertight and weatherproof joint where the plates meet." He does not say how light or how far apart the carlins are to be. He says he will put some canvas on the deck, but I do not know how he will put it there. I did not know any one had found out how to do that as yet. There was one steel vessel constructed in Germany, in which they had put down a steel deck, and tried to put canvas on it. They sewed the canvas and then put it on the deck with glue, but the canvas only kept in position on the deck long enough for the boat to come from Europe to America. They then put a $1\frac{1}{4}$-inch wooden deck on top of the steel deck and fastened the canvas in the usual way. I believed that proved satisfactory.

As I say, Mr. Donnelly does not tell us anything as to the proposed cost of the vessel, and there is no information regarding the weights, and so we cannot answer any of these questions as to how much she will weigh or the probable cost. Hudson River steamers do not count for much, apparently, according to one gentleman, because the Sound steamers have hotel accommodations aboard. The gentleman seems to have lost sight of the fact that there are anything but excursion steamers going up the Hudson River. We have some steamers on which we do carry a few passengers, say 2,000 in number, and feed them. We carry, as a matter of fact, about 2,000 tons of freight in addition, in very shallow water and narrow channels.

The statement is made in the paper that between the time the boat lies up in the fall of the year and the following spring when she undertakes the excursion business again, she could be laid up at some small town and furnish that town with electric light and power, etc., but what will the inhabitants of that town do for the four or five months during the summer when the boat is in its regular excursion business and is not available for furnishing light to the town? My idea is that they do most of the manufacturing in the summer time and are then in need of this power, and not in the winter months.

The last item in the paper goes to show that there would be a great saving in coal by the adoption of the type of vessel described, that at least $9,000 could be saved in coal. I would like to make a statement that the amount of coal consumed by the Grand Republic this year for eighty days, which is her usual term of service, and which is all she runs, amounted to a total of 1,920 tons, that cost $5,760. That is the sum total of the entire cost of the coal, and how a man is going to save $9,000 out of that, I fail to discover.

Mr. W. L. R. Emmet, *Member:*—The subject of this paper is principally that

of excursion vessels rather than that of the special method of propelling them, and I am not at all familiar with the particular needs in this case, but there are a few ideas which suggest themselves to an outsider in the course of the remarks which have been made on this paper. Anybody who has traveled around the world knows that every locality has its own kind of boats, and nobody has found a way of making the people of one place use the kind of boat which the people of another place have devised, and there is no boat anywhere in the world that is more characteristic of its locality than the side-wheel beam-engine steamer as seen in New York Harbor. When this subject comes up for discussion, it is interesting to hear the views of the men who know that boat and know the business of building her and running her. But in engineering we must look at all sides of the case, and while marine architecture in certain localities is very conservative, engineering is essentially progressive and always changing.

Now, what has been said at great length about the safety of a wooden or iron vessel is obvious to everybody. We all know that many things spoken of as dangerous are really safe as compared with the risks of our ordinary lives, but we want to consider that people go a long way to make a small improvement; they do it as a matter of sentiment and principle. I suppose that the New Haven Railroad carries about one million passengers a day, and I do not remember ever having heard of one of them being burned alive, and yet they go to steel cars, and a steel car is just as difficult a thing and just as inconvenient a thing to make as a steel superstructure on a boat. Furthermore, we cannot say how simple or effective the steel superstructure might be made by careful study, and I think the effort to make such study ought to be treated with due respect.

As to the general type of the boats and their method of propulsion, Mr. Donnelly's statements as to the inadequate design of existing boats of this class, while they may be subject to criticism in regard to detail, are in the main certainly true. Some of the large side-wheelers on the Hudson are using 40 pounds steam pressure and types of engines which, from the modern standpoint, are regarded as very crude, but the defence of them is that they are thoroughly practicable and are built very cheaply and can be operated very cheaply. The reason they are built cheaply is largely, I think, that they are so well understood and standardized. On account of these low speeds these engines are quite heavy, and when you study them point by point there is a good deal of work on them.

Comparing the methods of propulsion proposed in this case, we must consider that the turbine, the high-speed turbine, such as Mr. Donnelly proposes to use in this case, is a device far simpler than the reciprocating engine of any type, and turbines which would propel this vessel are not materially larger than our president's desk, and are of such proportions that two or three men could lift the top off them. They only have two wheels with two rows of buckets on each wheel, and with any one row of these four rows of buckets the ship could be run at half speed. The shafts are very large in diameter and there is nothing to the mechanism but two bearings. Such a device is very simple to repair and it requires practically no expense to operate such a device.

To illustrate the simplicity of large electrical apparatus I will give you an example. The Detroit Edison Company is operating a large substation out in the suburbs of Detroit, without any attendant in it. As a matter of precaution in starting this new type they have so far gone through the form of sending a man there to watch it, to make sure that its automatic functions were operating correctly. The processes of starting that substation, synchronizing it and getting it on to the circuit, and getting it to work, are all accomplished from distant stations, directly and simply. The reason for this possibility is that they are using simple rotation and there is no mechanical functioning which has to be performed. Electrical functions do not need personal contact for their performance. They can be performed from a distance, and the mere closing of switches is a very simple matter. The ordinary electric functions performed in a hotel in connection with the annunciating systems, and all those things, are often much more complicated than anything which it would ever be necessary to do on board ship, and the chances from trouble from one of these little devices in connection with every room in the hotel is as great as that essentially associated with the electric machinery necessary to drive a ship. The fact that it involves large amounts of power makes it less familiar to the ordinary individual, but the simplicity is still there.

The economy in the application of this method of propulsion to this vessel is a question, in my opinion, much more of the propelling device than of the prime mover, although I have no reason to suppose that the propelling device proposed would not be good. I could imagine that in shallow water there might be some difficulties about getting a high efficiency of propulsion, and that conditions of such a character might outweigh advantages in fuel economy incident to the better prime mover, but as to the economy of the prime mover itself there can be no question.

It will take far less steam than the reciprocating engine which would be used for such a type of vessel.

One reason for using the side wheels on such vessels I have always understood is the absence of vibration, the vibration of propellers being apt to shake the superstructure. I think in this boat Mr. Donnelly does not have to deal with this question so much, because it is not a boat upon which people sleep, but with three propellers of high speed I should think that would not be serious, but I personally have no knowledge as to how effective this propeller might be, and suggest it as a subject for interesting discussion.

The electric design proposed in this paper, which Mr. Donnelly has himself decided upon, is the result of experience with dredges, I understand. The method of control of the speed of the motors is one that is commonly used in various forms of application of induction motors to such things as hoists, and it is done by cutting resistance into the secondary of the motor and so slowing it down without interfering with the continuity of voltage or frequency on the driving circuit. All the methods of electric propulsion which I have proposed have involved a slowing down of the turbine, or in direct current control apparatus a change of voltage, and a control of the speed of the vessels by the turbine. In this case it is proposed to increase the resistance in the rotor of the motor. Increasing the resistance will slow the motor

down and bring it nearly to rest, and then it will be reversed and brought up the other way. By this means the control will be similar to the direct-current control used on the Chicago fireboats, and to do this you will simply work a contact lever in the pilot-house and by so doing reduce the speed of the motor and reverse it, and raise it again, so that the only action in controlling the boat will be moving that lever. That method does not give the best economy at low speed. There is certain loss due to the resistance at low speed. At high speeds it would be as economical as other methods. If a ship wanted to run continuously at low speed you could lower the speed of the turbine and lower the voltage of the turbine simply to adapt it to continuous operation at low speed with a better degree of economy than you have to simply control it by resistance.

Mr. Donnelly brought this design to me just exactly as it stands. I approve of its practicability; it is entirely practical and perfectly simple. The turbines would work reliably and do what he said they would do, and the electrical control would be perfectly satisfactory, and any motor speeded up or slowed down or reversed at will from the pilot-house without any complication that does not enter into the operation of electric locomotives and a hundred other things.

One other point, as to the question of auxiliaries—it is proposed to operate the principal auxiliaries by steam turbines. I think in this vessel, since you maintain a continued voltage and frequency on the prime mover, that these auxiliaries should be run by motors. The use of steam turbines for such purpose is extremely wasteful of steam, whereas the motor gives you power from the prime mover at the very least loss. There are various stations I know of in which these turbine-driven auxiliaries are being operated, in which I am sure that many hundreds of kilowatts could be put upon the busbars if they were taken out, but still, since they involve simple rotation, they are eminently practicable, and they have been introduced there from considerations of convenience. You are simply blowing these auxiliaries around with a jet of steam, just as you do the prime mover, and the thing is ideal and simple, but the electric motor which would do the work is also ideal and simple.

Mr. S. D. McComb, *Member:*—I would like to say a few words regarding the fireproofing features. I believe that the ships around New York Harbor could be made much better from a fireproof standpoint than they are, and that our shipbuilders around New York are not doing as good work along these lines as the shipbuilders on the Great Lakes are doing. The steamer, City of Detroit, which was built at Detroit last year, and the new Cee and Bee now building there, are much safer from a fire standpoint than any of the boats that have been built here.

It is true that we have boats which have steel hulls, and some have steel decks and steel engine and boiler casings all the way up, but most of these have their carline and partitions all of wood, and there are a lot of furnishings and decorations of very inflammable material in various parts of the boats. On the Great Lakes a great many of the passenger boats are sprinkled, and the new passenger boats are practically all sprinkled. While it is true that the Commonwealth and Plymouth

are equipped with sprinkler systems, the new Hudson River boat being built at Hoboken and the one at Camden, I understand, will not be equipped with sprinklers. In my opinion shipbuilders all over the country should install sprinkling equipments in the passenger steamers, especially those with large wooden upper works, which would materially reduce the losses by fire, and they would not increase the cost of the boats very much.

In freight steamers the principal danger of fire is from fire originating in the coal bunkers or in the cargo. The coal bunker fires have nearly all been due to the old coal remaining in the bottom of the bunkers. As the coal is used a few tons are allowed to remain in the bottom, and the ship is coaled up again. The coal will be used down to near the botton and fresh coal put in again. This process is repeated indefinitely, and the old coal is allowed to remain. It is this coal which takes fire. If some system could be devised so that the coal in the bunker would be used up completely, and none of the old coal allowed to remain, the number of cases of spontaneous combustion would be greatly reduced. At the meeting two years ago the Fire Chief attended, and spoke of putting a system of perforated pipes through the cargo space, so that water could be pumped into any hold of the ship where there was a fire. There are some vessels now that are fitted with steam extinguishers, but it would be very much better to use water than steam, on account of the greater cooling effect. There are experiments being made now which may interest our naval architects, that is, installing small perforated pipes for the use of pyrene in the hold of the cargo steamers. Pyrene has done some wonderful things, and it is probably the most efficient substance for extinguishing fires that is known. Pyrene extinguishers are now installed in all of the subway trains, as it is the only extinguisher that is a non-conductor of electricity. With this installation the pipes can be made extremely small, and kept clear of the cargo, and yet be made very efficient.

Mr. A. Fletcher, I think, spoke of a ratio of one-tenth of one per cent being killed of all of the four million passengers carried. While this may appear to be a very low percentage, it means that four thousand people have been killed in the last ten years on our steam vessels, and that number is entirely too large. There are two arguments that have been used by shipowners and shipbuilders against installing sprinkler systems and other fire-extinguishing devices in the holds of steamers. One is that the fire insurance underwriters or marine underwriters will not allow a sufficient reduction in the premiums to pay for the cost of this installation. They usually want a reduction that will make up the entire cost in two or three years. There are other things to consider, however, than a reduction in the insurance rate. An owner may be reimbursed by the underwriters for a loss on a boat, but this does not pay for loss of life or personal injury, or for the loss of the earnings of the boat until it is repaired or replaced. The other argument is that the vessel is equipped to comply with the law. I do not believe that any good naval architect or shipbuilder considers the steamboat inspection law requiring the highest type of construction possible, and I think our naval architects should

try to produce boats, not only to meet the requirements of the law, but which would be in advance of the law, and be as safe in every respect as they could reasonably be made. I would like our naval architects to consider more seriously the installation of sprinkler systems, both in the quarters for passengers and also in the cargo space. The architects and engineers of our buildings have taken up this question very thoroughly, and there is a great deal of data on the subject that can be obtained, and I think it would pay the shipowners, as well as the naval architects and builders, to investigate carefully this question of sprinkler systems.

Mr. Wm. H. Fletcher:—Are you familiar with the conditions on the Lakes in regard to the passenger steamer service?

Mr. McComb:—Somewhat, as I have been around that part of the country a good deal.

Mr. Wm. H. Fletcher:—Do you know what the fare is from Buffalo to Detroit?

Mr. McComb:—I do not know the fare, but I do know that these vessels are successfully run in competition with the railroads.

Mr. Wm. H. Fletcher:—I believe the large passenger steamers on the Lakes which have been referred to, get about double the fare that the Hudson River steamers do for transporting passengers practically the same distance. Therefore, in making comparisons, one must consider the existing conditions, and the naval architect must consider the amount the owner can realize from the operating standpoint in designing his vessel and in considering her equipment.

Mr. Stevenson Taylor, *President:*—I naturally read with a great deal of interest the paper prepared by Mr. Donnelly, and, preliminarily, I will express my belief that we are greatly indebted to him for the preparation of that paper for, if it has done nothing else, it has brought forth that which is most important in this Society, namely, the discussion of the various phases of the business of naval architecture and marine engineering. After hearing the remarks of one or two of the speakers upon this paper I concluded not to add to the discussion, but Mr. Wm. H. Fletcher has called upon me to state to you what happened some years ago when the steamers Monmouth and Sandy Hook were compared to the steamer New York. I cannot give you the exact figures, for it is many years ago, and I can only give you the results from memory.

The steamers Monmouth and Sandy Hook are well-known steamers, running from New York to Sandy Hook, a distance of about twenty miles, and they only run in the summer time. They were well known as very fast steamers, particularly so as they came in competition, so far as speed is concerned, with no other fast steamer. When we built the steamer New York for the Albany Day Line, we tried to make the fastest steamer of the kind that had been built up to that time, and having been connected for forty years out of the sixty years that Mr. Andrew

Fletcher referred to as to the life of his concern, I can, of course, substantiate anything he says in support of the claims of these steamers.

Mr. J. Rogers Maxwell, at that time President of the Central Railroad of New Jersey, and Commodore Van Sant Voord, the owner of the Hudson River Day Line, were both very good friends of mine, and I tried to persuade Mr. Maxwell to build a boat like the New York for the Sandy Hook route, but he was always progressive and he naturally felt that triple-expansion engines and twin-screw propellers were the best to adopt. I happened to say to him one day—"I would like to take the New York down the bay and run her on your route, and show you what she can do." He responded by saying, "Perhaps we had better race the boats down there." I told Mr. Maxwell I would try to do that, though, really, I had no faith I could induce the most conservative man I ever knew, so far as the safety of life and property is concerned, Commodore Van Santvoord, to indulge in a race of this character, but my sporting blood was up, and I took the matter up with him. As Mr. Fletcher has said, to the surprise of everybody he consented to race the steamer New York against either the Monmouth or the Sandy Hook, though the Monmouth at that time was a favorite. Back I went to Mr. Maxwell and tried to arrange what would have been a most interesting race. Mr. Maxwell smiled and said: "As it is now, we both have the fastest boat. If we had a race, one of us would be beaten. I guess we will not have the race." (Laughter.)

As to the relative economy of the two boats for their purpose, bear in mind these things must be considered and determined on the basis of the purpose for which the boats were designed and constructed. In these boats we had two examples, the twin-screw fast-running boat, used for a short period in the summer time, on one side, and our good old familiar friend, whom I will not stand to see abused, the beam-engined steamer New York, on the other side, running about the same length of time, and the figures then showed that at the end of the year, when everything was considered, the New York was the more economical boat.

The difficulty with the paper which Mr. Donnelly has presented is simply this: He has made a number of statements that seem to me to be unwise. If he had kept strictly to his subject, without indulging in certain comparisons, this discussion would have been avoided; but then you would have lost the experiences you have gained. Perhaps, after all, it is better so.

Mr. Donnelly presents only a combination of details, every one of which has been used before or suggested.

He refers to the steel structure of hulls, to the double bottom and double sides, examples of which are numerous. Incidentally, the construction of a boat on the plan suggested by him, in my opinion, could not be taken care of and would have to be modified very much. The steel structure surrounding the boiler and engines is not new; we have done that for years on certain boats. The centrifugal feed pump that he mentions as though new is now being built and installed by a company in this city. The Favorite, built about 1882, was a triple-screw excursion

boat. Of course the author does not claim what the builder of that boat claimed, that, having three screws, each screw would propel her 8 miles an hour, and the use of the three screws would give a speed of 24 miles an hour. One screw was later taken out, because they found they could handle the boat better with two screws. The scheme of an electrically driven boat has been discussed in the papers presented to this Society by Mr. Emmet. Fireproofing construction has been discussed as far back as 1906, and, notwithstanding the author's statement that it is incomprehensible that this subject has not received more careful consideration, I will say that it has received very careful consideration in the last twenty-five years to my personal knowledge, and nothing but the impracticability of constructing boats of this type for other purposes than excursion boats has kept them from having been constructed. The twin-screw steamer Ox, in this harbor for at least forty years, has had pilot-house control of all machinery on board.

So, as I say, further than a combination, there is nothing new suggested in this paper; notwithstanding that, gentlemen, and notwithstanding the fact that excursion boats and other boats have carried for many years billions of passengers with extraordinary safety; with far greater safety than attends the people of the city of New York in traversing its streets, as has been shown by figures given in the Proceedings of this Society, far greater safety than one can travel on the railroads; while life on steamboats has been extraordinarily safe, we must recognize that it is quite within the range of possibility that a passenger steamer will be destroyed by fire despite all our efforts, despite the claims that I have made here before you in times past that a good line, with good discipline, will not have a steamer burn up in service, it may happen, and we should do everything we can to make the lives of passengers still safer on baots. Anything that will tend to do that, and tend to make progress, should be warmly welcomed, and earnestly, seriously considered.

Mr. Andrew Fletcher:—I want to suggest to Mr. Emmet that he is somewhat in error as to his statement that the boats on the Hudson River were running with 40 pounds of steam. I wish to say that some of them are running with 170 pounds of steam, such as the Day Line steamer Hendrick Hudson.

One of the speakers, Mr. McComb, referred to the great loss of life traveling by water. I wish to state that the records show that there was a loss of one in each 1,611,998 passengers carried by excursion steamers in this congested Second Government District. The records of the Board of Health of the city of New York show that during the period of 1899 to 1911, inclusive, there was one life lost in each 1,871 of population by accident, and that when accidents, suicides, murders, sunstrokes, and all other causes were taken into consideration, that there were 44,071 lives lost, which would make it one in 1,198 in comparison with one in 1,611,998 of passengers carried by water transportation in the Second Government District from 1900 to 1910, inclusive. This is a startling difference in favor of water transportation.

MR. ENGLIS:—In relation to the engine of the Grand Republic, Mr. Taylor calls my attention to something which had slipped my mind. The engines which were in the Grand Republic were originally built for the steamer Cosmopolitan, which was constructed by my father, John Englis, and launched at Buffalo on Lake Erie in 1853. The engines were taken out of the Cosmopolitan about 1862 and put into the steamship Morro Castle, and from the Morro Castle they were put into the Grand Republic in 1878.

MR. WM. H. FLETCHER:—The New York, built in 1887, was a typical passenger excursion boat. On an excursion boat built to-day there would hardly be any appreciable change. She was an airy, open boat built for carrying a large number of people on excursions up the Hudson River or down the bay. She developed 3,000 indicated horse-power on her trial trip and is therefore of a type in line with the paper.

MR. DONNELLY:—Will you put in the steam economy as to what it was?

MR. WM. H. FLETCHER:—There was no actual test made of the power economy, but only of the entire power equipment, namely, coal, oil, labor and all that went into the actual running of the boat. I do not mean by that to include the captain, deck hands and others, but simply the cost of propelling the boat only, and, as I remember, the New York showed an appreciable economy.

MR. DONNELLY:—I certainly wish to thank the members who have discussed this paper so frankly and openly, and I shall try to answer such remarks as I can. I hope, if there is any point I do not refer to, that you will ask me to do so.

Mr. Fletcher, as we all know, has been the guardian, if not the originator, of the class of boats referred to, and I think perhaps his works was one of the first to put out this class of boats. I wish to make a general statement to apply to the remarks that have covered a much broader field than the subject under discussion.

The class of boats referred to does not include all the boats on the North River and Hudson River, it is not the Sound boats, it is not the boats using feathering paddles, it is not the boats using a compound beam engine, it is not the boats with engines making forty turns per minute, nor the boats with 140 pounds pressure that we are considering. The discussion is limited to the summer excursion fleet, and the principal representative of this fleet, the best of them all, is the Grand Republic.

Keeping this in mind, I do not find that Mr. Andrew Fletcher made any statement that would contradict the accuracy and applicability of the statements made in the paper. He questions the economy of the engines. I am very well aware that very much better economy can be gotten with the feathering paddle and with a large number of revolutions, but we do not have them in the excursion fleet. I am directing this paper particularly to that class of boats and I think that it so specifically stated in the paper.

The matter of the weight and economy of the engines of the class of steamers under discussion I am going to refer to Mr. Orrock, the joint author of this paper.

Regarding the loss of life which has been taken up in such great length and detail, it is not a question of the number in a million who are lost or because three or four persons in a million in the city of New York lose their lives, for I am one in a million and I do not care to sacrifice my life on that account.

It would be desirable to have from the excursion steamboat company a statement which would show the falling off in the excursion business immediately after the fire on the General Slocum. The excursion business in New York Harbor has often increased very rapidly, but has fallen back directly upon a serious accident taking place. We, as engineers, are dealing with progress and development. We are not dealing with business as it exists to-day, or protecting property in existence to-day, as against property to be created. We are dealing primarily with property to be created. I could understand a very natural motive, on the part of all steamboat owners of the present day, to maintain that the boats they have are the very best that can be made for their purpose, but that position might have been maintained relative to any buildings in existence before we commenced this era of fireproof buildings. It cannot be maintained to-day; and whether we will or will not be able to produce a steamboat which is really fireproof, is something which remains to be seen, but if it can be produced and is found to be practical, then it will be the new standard of construction and will be continued.

In this paper we have simply taken a problem which exists and shown the steps which to us are apparent and can be accomplished.

The second speaker, Mr. Berry, spoke of the cost of operation. The cost of operation of these boats, if we are to consider them as a power-producing plant and means of transportation, should be less. Whether it can be shown to be so, is something which has to be taken up and tested out. As to the matter of the greater amount of power, certainly there is a greater amount of power. If an engineer has learned anything, broadly speaking, he has learned that if he has to undertake any problem which is, in any degree, new, the one thing which he should have is plenty of power. It is not necessary that he should use all the power, but have it there, and in advancing any form to construction which is an improvement over previous production, it is desirable to have a surplus amount of power.

As to increase in cost, there certainly would be an increase in cost, but we would never have had the modern office building if some one had not had the initiative and courage to increase the cost of construction of those buildings. There is nothing in our modern life but shows increased investment, two or three times over in many lines, and the result is economy of operation, earning power and maintenance, and I think the whole tendency of modern development is toward greater investment and surer return on money.

As to the remarks of Mr. William H. Fletcher, he stated that the cost would be too great. It is simply a matter of the cost as against the earning power.

My experience with regard to the number of people traveling on these excursion

boats is that at the present time the excursion business is confined to a very limited class of people who are willing to use these boats. There is a vast population in this neighborhood that I believe would take advantage of the summer excursion pleasure trips if the same attractive features which they find in other places were shown them. That is a matter, however, entirely within the judgment of business men, and unless the judgment of business men agrees to that proposition, we will not have the fireproof excursion steamers. If they do, we will have the steamers, and then we can thresh out the results of the operation of them.

Mr. William H. Fletcher claims we made an unfair comparison with the Grand Republic on account of the conditions of this old steamboat. We think it is the best that could be made. It stands at the head of the summer excursion fleet in this vicinity. We did not make the comparison with a New York and Albany boat or with a boat of the Fall River Line, because we are not discussing that class, and we are not attacking any class of boats. I can see, though, as these gentlemen say, that there will be a reflection on that class of steamers if a strictly fireproof steamer is built. That they must stand. I do not see any reason for stopping the progress of the art of shipbuilding where it is because the reflection will not be entirely satisfactory on the vessels now built.

The danger is said to be very small. That is brought out repeatedly. It is not a question of the danger, or how small it is, but it is a question—Can we make it smaller? We have made progress in every other line and it seems that we should, as engineers, do all we can to make progress in this line.

Relative to the remarks of Mr. Dickie, who spoke of the surface condenser, if there is a mistake in the paper as to when the surface condenser was invented, that will be corrected.

As to the economy of the oscillating engine, certainly with the feathering paddle and the oscillating engine, as developed in the practice of Scotland, very much higher economies are obtained, but I am making a comparison with the single-cylinder engine, making from sixteen to seventeen turns a minute. I will refer this matter to Mr. Orrok for a more complete reply.

I was pleased to have Mr. Englis speak as he did of the construction of these boats and their cost. I think that a cost of $100,000 thirty-four years ago for a wooden boat would probably compare with a cost of $250,000 or more to-day, as to the relative investment which would be required in these boats. The amount that should be expended is entirely a matter of judgment.

In the matter of entertaining people, my experience is that we must furnish the best that can be had, and then something better. There has been built hotel after hotel in New York City, and the designers of these hotels have searched Europe for extravagant adornments for dining rooms, drawing rooms and other rooms in the hotel, and it is not found that we have reached the limit as to cost yet. It seems to me if you are going to entertain people on the water in a steamer, that some similar way of looking at the problem might have some commercial value, but that is a matter for commercial people to settle and not for the engineer, but

it is for the engineer to show the possibility of a construction which is safe and permanent and will match up with the progress and developments that have been made in other lines.

Mr. Englis has had more experience than any one else in the matter of the superstructure of these boats, and it was through an oversight that the plan showing the superstructure of the boat in question, the carlins, etc., was omitted from the paper. In my judgment, there is no question that a satisfactory fireproof deck and carlin can be made. It would be an ordinary engineering precaution before commencing the construction of the steamboat, to build a full-sized section of the deck and thoroughly test it.

In the matter of saving coal, the figures given in the paper are based on the performance of the vessel at full power. The figures bear this out. I am delighted to know that the Grand Republic can be run for a season of eighty days on an output of $5,760 for coal, and I thank Mr. Englis for the information.

Mr. Emmet has referred to the matter of machinery and the power in this vessel. I think there is no better authority as to what may be expected from electrical apparatus than Mr. Emmet. His standing in such matters is well known. In regard to the auxiliaries, as to whether they should be steam or electric, I would like to refer that to my associate in this paper, who has had the very largest experience in such matters.

One of the speakers, Mr. McComb, spoke of the Great Lakes and the fireproofing of the boats which run on the lakes and the use of sprinklers. I do not know but what we are all advancing about as rapidly as can be expected in these matters. It is well to call attention to what is being done at the different localities and to exchange information on such matters.

Mr. Taylor has spoken of the Monmouth and the New York. These steamers are entirely out of the class this paper was intended to consider. In the comparison that was made in the cost of carrying a passenger, it should have been explained what was the data used in making the comparisons. I should judge the steamer New York, running between New York and Albany, carried several times the number of passengers on a trip that the Monmouth did, and that the cost per passenger might be reduced on that account.

Mr. Taylor asserts that I have not introduced anything particularly new. That should be to the merit of the paper rather than otherwise, for if we can make a new combination of old elements and produce something which these gentlemen all admit would be superior, and the only serious objection they make is that it is not commercial and would cost too much—if we can do that, the engineer is exercising his highest function in the structure as submitted.

We have tried to bring together the latest that has been developed in the production of power, the best that has been done in the matter of hull and superstructure, and in all other parts of the ship, and whether we have gone beyond what is possible from the investor's point of view, that must be met and decided in a practical way.

Mr. Taylor:—Referring to Mr. Donnelly's comment on my remarks, I will say that no comparison was made by me "on the cost of carrying a passenger."

It was on the special request made by Mr. W. H. Fletcher that I referred at all to the steamers Monmouth and New York, and the comparison as to the relative economy in operation of these two steamers of practically the same speed was based on the facts that both were used only for carrying passengers and only for the summer season; that taking into consideration the original cost of machinery and the cost of operating same, the cost of repairs and upkeep, counting interest as well as cost of fuel and other necessaries, the New York was the more economical per mile run regardless of the number of passengers carried. Of course, were the steamers in question used all of the year, the results might be different.

Mr. Andrew Fletcher:—Mr. Donnelly stated that I had not argued the question as to the modern, short-service excursion boats. When we bring the matter right down to modern excursion boats built for this New York service, there have been but few built; the latest one is the Thomas Patten, a steel hull boat with walking beam engine, feathering paddle-wheels, boiler enclosed with steel casings to and including the hurricane deck, with the engine making about 600 feet of piston speed per minute, against the Grand Republic with 400 feet of piston speed. On Lake George and Lake Champlain we have built in recent years a number of steel excursion boats, in which the improvements of recent years in construction have been incorporated.

Mr. Orrok:—Referring to the statement that the machinery weights for excursion steamers varied between .2 and .25 tons per indicated horse-power, without doubt Mr. Andrew Fletcher has much unpublished data which was not available to the authors in preparing this paper. We found much difficulty in getting the actual test figures of the few steamers which we knew had been tested. These figures in regard to the Mary Powell, the Rhode Island, the Bergen and Orange and some others are available but, as is the case with seagoing steamers, such tests are seldom made and much more rarely published. It would be of great value to the Society if Mr. Fletcher would put some of the vast amount of data of this kind which he must have in shape for publication. The weights as above stated include boilers, piping, auxiliaries, main engines, girders, shafts and wheels and everything excepting winches, capstans and equipment of that character.

Replying to Mr. Dickie, the surface condenser was patented by Watt in 1765, Cartwright in 1794, Brunnell in 1822, and by Hall in 1831. Hall's condenser, in which the water was outside of the tubes and the steam passed through them, was the first one to be fitted in a steamship. This vessel was the Hercules, sailing on the London-Cork route in 1837. A similar condenser was fitted on the Megara in 1838, and the Sirius, the first Atlantic liner to make the voyage under steam from England to America, had a Hall condenser which was used during the voyage. Hall's con-

denser, however, was not a success, partly because of the low steam pressure and poor design and partly on account of the use of tallow as a lubricant. The tallow, decomposed by the heat of the steam, formed soluble copper salts which rapidly attacked the iron plates and tubes of the boilers. During this same year, 1838, John Bourne patented the counter-current principle and the carrying of the water in the tubes instead of around them. He did not, however, apply this to marine work until much later, and the first modern condenser of which I have record installed in a ship was put in the Alar in August, 1857. About the same time Pirrson's condenser, a combination of surface and jet, came into use to some extent in marine vessels. Mr. J. F. Spencer also had considerable to do with the introduction of the surface condenser in marine use, which must have occurred in the years between 1858 and 1862, although I have no direct records of this.

The Chairman (Admiral Capps):—I will now have to enforce our rules as to time occupied in discussion of papers. Nothing but the requirements of other papers would cause the Chairman to curtail the discussion at this point. I think, however, the Society will be only too glad to receive additional comment if members feel so inclined. This comment may be written out and sent to the Secretary, and, as is always the case, the author of the paper will have the opportunity of summing up and saying the last word.

I think the discussion that has developed this morning has admirably brought out one of the principal objects of this Society, which is, the diffusion of knowledge concerning shipbuilding by an interchange of views of members who have had experience; and nothing seems to bring out the best results in an experience meeting than to have advanced a few opinions of widely different character. I think the Society is to be congratulated upon the discussion which has taken place this morning, and I know you will permit me to thank Mr. Donnelly on behalf of the Society for his efforts in bringing forth this discussion.

On account of the limited time at our disposal the next paper on the list, entitled "Notes on Fuel Economy as Influenced by Ship Design," by Mr. E. H. Rigg, will be read at the afternoon session, and the next paper to be presented at this sitting will be that entitled "Active Type of Stabilizing Gyro," by Mr. Elmer A. Sperry, Member of the Society. This paper will be presented now so that advantage can be taken of arrangements made to project certain illustrations on the screen.

ACTIVE TYPE OF STABILIZING GYRO.

By Elmer A. Sperry, Esq., Member.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

The navies of the world, in the struggle for supremacy, are making for maritime progress as no other force could. These developments, considered strictly from the present-day standpoint of conservation, more than justify the entire expenditure, and though remaining for a time in the possession of one nation, soon become world property. Our own navy has been in the forefront of this progress. Consider the recent great advancement of knowledge on the relation between form-line, speed and power of ships; very largely the product of our own model tank at Washington, due to the broad policies and wonderful foresight of our navy and the rare ability and devotion of its personnel. The marked reduction in fuel, in many instances halving the fuel requirements in marine transportation, is certainly a proud monument to any navy and one our own nation should be proud of. And this is only one of its achievements, all accomplished so quietly that the nation does not realize nor appreciate it as do the more maritime nations over the seas. These may all be considered as "by-products," simply incidental to the real development or the real significance of the navy in its relation to our place among the nations.

The engineers of our navy have been responsible for numerous advances in power and fuel economy, not only by establishing efficient and scientific methods of managing boiler and engine plants, but also by numerous improvements in the design of engine itself.

The subject with which this paper deals is one that has received attention and has for some time been under investigation by the architects of our navy. Two years ago I was permitted to touch upon some small portion of this work; since that time the progress has been marked. In fact, with the data now available, it is possible to design a stabilizing plant which will confine the roll of a ship to almost any limit desired, regardless of the displacement and period of that ship. The same type of plant may be used for rolling the ship at will, which feature has an important application in our icebound waters.

It is felt that when the data relating to the active type of gyros is ready

to be given to the world, the important subject of stabilizing ships will receive by far its most interesting chapter and not unlikely its most important contribution.

The advantages to be derived by efficiently stabilizing ships may be summarized as follows:—

I. ADVANTAGES COMMON TO ALL SEAGOING SHIPS.

(*a*) Saving in power and consequent saving in fuel owing to the ability to maintain the shortest course between two points in bad weather, inasmuch as the ship will be in no danger from excessive rolling when steaming even in the trough of the sea.

(*b*) Saving in power and consequent saving in fuel owing to the fact that the wetted surface is not increased by wallowing, inasmuch as the vessel is always held on an even keel.

(*c*) Saving in power and consequent saving in fuel by elimination of rolling against the relatively stiff water when under way. This increase in the power required to drive a vessel which is rolling is due to what is known as the keel or form line impingent. It is illustrated by the far shorter extinction curve of the roll of the vessel when steaming than when not under way.

(*d*) Saving in power and consequent saving in fuel by reducing the yawing and tendency to follow a sinuous course.

(*e*) Saving in fuel and weight by the elimination of bilge keels.

(*f*) Making small ships as comfortable for passengers as large ships, while at the same time being able to prevent the largest from rolling.

(*g*) Eliminating stresses in the structure of the ship and the stresses in the accessories and auxiliaries contained within the ship, which are caused by excessive rolling.

(*h*) Preventing deterioration in cargo caused by excessive rolling. This would particularly apply to ships carrying live stock as cargo.

(*i*) Ability to roll the ship artificially for the purpose of freeing from or rolling off sand or mud banks by opening the contacting crevices and gradually liquifying the encumbent mass.

(*j*) Making a ship more seaworthy by preventing the shipping of seas due to rolling.

(*k*) Vastly increasing the efficiency, certainty and range of usefulness of ice breakers; in fact opening up a whole new field of operations for this important class of ship.

2. ADVANTAGES APPLYING ESPECIALLY TO MEN-OF-WAR.

(*a*) Decreasing the amount of under-water armor, which it is necessary to place on men-of-war at present in order to protect that portion of the hull which might be exposed to the enemy by rolling.

(*b*) Steady gun platform.

(*c*) Ability to go into action in any state of sea or upon any course in rough weather.

(*d*) Improving the condition of men and officers by eliminating the fatiguing and other effects of incessant and constant rolling.

(*e*) Ability to roll the ship artifically to standard angles, as desired, in competitive target practice.

Since the unique and enlightening discussion recorded in the last proceedings of the British Institution of Naval Architects, the character and extent of the early work of Sir Philip Watts, Professor Biles and others in attempts at improving the stability of ships by the use of damping tanks, in England, have been better understood. The original detailed proposition of Sir Philip for the construction of the tanks on the Invincible and other ships has also become known, and the completeness of their understanding of the underlying principle of the operation of these tanks, namely, their necessary synchronism with the ship's period, for developing secondary resonance, leaves little to be desired.

Without dwelling upon the claims to originality which were made by the author of the paper which led the discussion, I think we all agree that he is entitled to much credit for his persistent work in this line and for the certain applications to ships which have resulted from these activities.

There is no doubt about the very great desirability of steady ships. We believe that shipping interests and the marine generally are indebted to the recent German workers for again bringing this important subject into prominence. Both Dr. Schlick and Herr Frahm have been working in the same line in one particular, namely, damping roll of ships after motion of some magnitude has set in. In point of fact, they diminish the amount of such roll by setting up counter forces having their origin in the motions themselves and depending upon such motions for their existence.

This meeting of the Institution was remarkable in a way, for there were present England's foremost thinkers and workers in this field—men who have achieved distinction and impressed the manifold results of their long-continued service upon both the navies and merchant service of the world.

Turning again to the operation of damping tanks in the original paper by Mr. Frahm, much stress is laid upon the point that the fundamental

principle of this operation, using his own words, "consists in setting up a secondary and artificial resonance in order to annihilate the primary resonance between waves and ship, it being on this fact that their operation is based."

The very grave question arises:—Is the basic proposition here enunciated true? Is there any primary resonance between waves and ship or really any approach to such a condition? This question was raised in this discussion by one of the nestors of this art, and a fact was pointed out by him which has been the basis of minute analysis on this side of the Atlantic for some years past, namely, the oft-recurring cycles, or groups, universally present in rolling records. The facts thus brought out by Sir John I. Thornycroft agree in the main with the results reached early in this investigation by similar analysis on this side. These cycles are to be seen in any rolling record, for instance, in Figs. 1, 2, and 3, Plate 79, where it will be seen that the rolling gradually increases to a maximum and then decreases to a minimum, whereupon another increase takes place, to be followed by another decrease and so on. The sea is doing work upon the ship for a time and then, in the words of Thornycroft, "it again undoes its work." In a very choppy sea the recurrence of these cycles is very much accentuated; the groups become smaller and less regular and sometimes more difficult to trace, but still they are there. This can point to but one conclusion, namely, the absence of anything that approaches true resonance between waves and ship. It also argues strongly against any stabilizing device which is limited to resonance phenomena only, be it primary or secondary resonance. Let us examine these curves more minutely. It will be observed that at the end of each cycle, before the next one starts, there is usually a change, more or less definite, in the phase of the period where there is an apparent "fault" in the regularity of the curves. The curves in Figs. 1 and 2, Plate 79, are taken from a very favorable sea, and when we examine curve 3, which is taken from a less favorable sea, we see that these faults are more numerous and occur with greater frequency. Inasmuch as this feature is characteristic of all rolling of ships, how can it be successfully attacked by a device the underlying principle of which depends upon periodicity and synchronism. The water in the damping tanks can only create its damping movements as a result of regular oscillations, and if this oscillation is irregular the reactions fail to be propagated, and when the period changes what force is there present to readjust the operation to the new condition? Of course the answer to all of these questions is that tanks do not dampen under these conditions. It is true that there are easy rolling conditions in an old sea where they show to the greatest advantage and the damping action amounts

to quite a comfortable percentage of the undamped rolling. But what are we to say of other sea conditions which are much more aggravated; and which, owing to their being more usual, are more important. It has been shown in this art that if the tanks are placed high and are supplied with water representing a sufficiently great percentage of the displacement of the ship the damping is good when the sea is synchronous, or approaches synchronism. But who is to guarantee the continuance of the synchronous condition? Certainly it does not exist on the high seas as we have found them.

Let us examine more minutely what happens when the sea is not sychronous. Let us consider the instances only slightly removed from synchronism. We find that the tanks have already practically failed to perform any useful function whatever and this approach or the percentage of the departure where they fail grows smaller and smaller as the seas grow heavier. Many curves have been analyzed with the tanks placed high, if not higher, and with the damping effect placed practically upon the conditions of the Ypiranga and Corcovado, where these tanks are placed at the highest point relative to the center of oscillation so far recorded. Upon an examination of these curves shown in Figs. 4 to 7, Plate 80, we discover that a departure of about 13 per cent in a comparatively calm sea, and of only about 9 per cent in a heavy sea, is sufficient to practically nullify the usefulness of the tanks.

A careful planimeter analysis of these curves which take into consideration the sum of all rolling motions of the boat over a given time, show that where the natural roll is given as 100 in each case, and under identical conditions, the rolling with all tanks in service amounts in Fig. 4 to 80; in Fig. 5 to 73, and in Fig. 6 to 68; whereas Fig. 7 shows that under full operation of the two damping tanks the area is 73.2. And in this latter case the departure of the wave impulse from true synchronism has only been $9\frac{1}{4}$ per cent. We can by no means consider any such performance as stabilizing the ship, nor in any sense of the word fulfilling the object before us; nor can it be considered as justifying the large burden in weight and the great amount of valuable space occupied amidships, in the position where space is most available and valuable for other purposes.

Again referring to the recorded action of these tanks, I do not think any of us would consider the performance shown in Figs. 4 to 7, Plate 80, as coming under the head of extinguished rolling or justifying the large expenditure of funds or of the boat's carrying capacity as stated.

It is sufficient to say that experience has demonstrated that damping tanks are disadvantageous, if not positively dangerous, when out of syn-

chronism or when their period is not adjusted to that of the ship and, when so adjusted, then at each time the phase changes. In this connection it will be of interest to note that the period of the ship varies with its speed. A change of 30 per cent has been noted in one instance between period of a ship at 15 knots and that at 0 knots, thus showing that the period undergoes changes from more than one disturbing factor.

The interesting work of Dr. Schlick in connection with the passive type of gyro was another effort in this same line which dealt with the motions and necessarily periodic motions of the ship after they had been developed by the actions of the sea, utilizing, as in the case of water tanks, the natural motions on the part of the ship in developing reactions for the purpose of damping oscillations of greater amplitude; thus in both cases some motion is primarily necessary. In the case of the original paper of Dr. Schlick, the accompanying mathematical treatise by Dr. A. Froebel was in fact entitled "Schlick's Gyroscopic Rolling Brake," the action being limited to the damping of roll and the suppression of excessive rolling. In descriptions of all of this work a favorite expression which is employed is that the "rolling was reduced six-tenths to one-half," etc.

It is to an entirely different method of operation that I wish to call your attention, where the object has been to deal with individual increments or energizations of the ship regardless of synchronism or any other relation they may bear to the rolling period of the ship. By thus completely neutralizing each energization at its beginning or inception the ship is prevented from taking on or setting up motion.

As was pointed out by me in a paper read before the Society two years ago, each individual energization of the ship, regardless of its direction, amount, or its relation to period, should be dealt with as it arises; in this manner dealing with and counteracting forces which are acting on the ship, as contradistinguished from damping the motion of the ship. The question of distinguishing between damping motion and resisting it was a year later quite distinctly stated by Sir John I. Thornycroft before the Royal Institution of Naval Architects and Marine Engineers at their London meeting. Sir John says that the perfect apparatus must not depend upon synchronism but must be entirely free from any synchronism between sea and ship, or between the period of the ship and that of the stabilizing apparatus. "The perfect stabilizer must act against the forces which are acting on the ship in such a way as to always resist the effect of the sea in producing motion." It has been found under service conditions that this is easily accomplished and is of full effect long before the ship has had time to get her great mass into the motion which constitutes rolling.

This stabilization of ships has been undertaken by two methods:—First, by changing the center of gravity of the mass as a whole, as by the damping tanks of Sir Philip Watts and later workers, and the moving weights already successfully applied by Sir John; and second, by employing the already very great longitudinal stability or rigidity by deflecting same in to the athwartship plane. The ship by this means may be rendered stable almost without limit and up to the breaking-down point of the gyroscopic couple, which has now come to be recognized as of simple origin and of very great magnitude, especially as compared with the weights involved.

Some of the early attempts to use the gyroscope were unfortunate in that the gyro was passive, therefore free and uncontrolled as to its precessional movements. Experience has now been had in actual sea trials which confirm statements often put forward by the author, urging the great importance of having these precessional movements of the gyro at all times under perfect control. This arrangement introduces into the art a number of very important advantages which are now of definite and proven worth. This control on the one hand sets a constant limit to the otherwise almost limitless power of the gyro couple, while on the other hand it allows us to apply a measured stress of any desired magnitude, duration or direction and that may be timed with precession. In this manner, the very great longitudinal metacentric height is available for athwartship purposes and may be in any desired amount added to the athwartship component. In fact the point has now been reached in this development, as demonstrated by sea trials, that the amount of the great longitudinal stability utilized athwartship may be always quantitative and proportional to the needs. With this auxiliary fitted the ship itself may be very tender and of low metacentric height because, as above stated, any desired amount of the very great longitudinal metacentric height may be added at will athwartship, and this without any regard to the rolling period of the ship. In this manner a comparatively small apparatus can be utilized in effectually holding the ship against motion, simply because each increment on the instant, and simultaneously with its development, is completely neutralized before it has time to move the ship.

The gyro constitutes an ideal apparatus for this work inasmuch as it is perfectly safe. It is unnecessary to run the wheel at any but comparatively low stresses. In fact, the stresses present can be brought below those used in hull practice. The comparatively slow motion of the wheel is very inexpensive to develop and maintain, representing only a small fraction of the power required to propel bilge keels; and this power, small as it is, is only required when the necessity for stabilizing arises and then only in proportion to the seas running at the time, whereas the power for the bilge keels is omni-

present; that is, it is a constant drag in all weathers. The power for operating the precession is trifling, only sufficient to absolutely control and limit the precession movements at all times. This arises from the fact that in stabilizing the constant tendency of the ship is to do precession-wise work upon the gyro. This is fully borne out in practice as it is found that the power required for the precession engine is almost nil, it being only sufficient to control the implacement of the positive and negative energizations delivered to the ship.

It must be remembered that the weight of Thornycroft was specifically seven times that of the water in the tanks. The gyroscope is ideal in another sense, for with it we have the weight of Thornycroft greatly augmented as to mass moment by the simple fact that it is in rotation, which constitutes a multiplier of tremendous magnitude, even though the actual rotative speed is comparatively low.

That Thornycroft was correct in his line of attack on this problem has now received emphatic confirmation. The effectiveness and mass moment of his weight have been mightily augmented on the one hand while on the other decreasing its gravity load upon the ship and at the same time never shifting its position with regard to the ship or changing the center of gravity of the latter in the slightest degree. If all these things had originally been in the hands of our distinguished contemporary it is impossible to predict the very great advance that the art of stabilizing ships would have by this time achieved, as only last year he stated:—"I came to the conclusion twenty years ago that it was possible to make ships perfectly steady."

In connection with dealing with each individual increment, let us for a moment again refer to Plate 79. As we trace the envelope of these curves in their rise and fall, as they are near the center line where the phase is usually shifted, there is always the first impulse of a new cycle, the one which sets the cycle. Now if no cycle of rolling ensued we would have simply a succession of these beginnings, which will naturally be of various signs and magnitudes. These are more numerous in a vigorous, choppy sea where, as stated, the cycles themselves are shorter and the individuals which shift the periods appear oftener. Now if each of these beginnings could be efficiently suppressed neither the cycles nor the individual rolling constituting these cycles would ever come into evidence, and it is just this suppression that we are enabled to effect by the active gyro.

Calculations dealing with a known tank equipment well illustrate the powers of the active gyro stabilizer. Let us take the case of Figs. 4 to 7, Plate 80, where acomparatively small fraction only of the roll was dampened, owing to the sea being out of synchronism even by but a slight percentage.

The active equipment, as we have seen, is different. It most promptly deals with each momentary energization and "has no memory;" it cares not when nor from what direction the previous stress attacked the ship.

The surprisingly small magnitude of the whole gyro equipment is due largely to its unique method of operation; that is, it makes up in activity and promptness what it may seem to lack in size and weight.

Herr Frahm mentions the tanks of the Ypiranga as changing the center of gravity of this vessel to the extent of some 2,700 foot-tons and states that gyros with this torque value had not been developed at that date. Gyroscopes can now be developed with low specific stresses of much greater torque value than this figure indicates, with the further gain that the center of gravity of the ship is not disturbed, nor would it undergo any change whatever. Moreover, with active gyros, torque of this magnitude is not required in ships of this tonnage and slow period for their effective stabilization. In connection with this statement regarding tanks, Herr Frahm failed to point out how many oscillations of the ship were required before reactions of this magnitude had been set up, or if developed by one or two large oscillations how great an amplitude was required in such oscillations of the ship. We now know what these are, and no ship could be considered stabilized while obsessed with this motion. One great difficulty with the tank proposition is that its phenomena are pendulous and resonant from start to finish, and must be in fact co-pendulous with the ship and therefore far too slow to deal with individual wave impulses. As a matter of fact, the first impulse or impulses are never dealt with, but instead the boat rolls in response to the increments in the act of creating the reaction within the tanks. Thus we see that as a matter of fact individual increments are never dealt with until an accumulation of a number of such impulses has resulted in actually rolling the ship, whereas the active gyro deals with each individual increment and no accumulation is possible.

Under the conditions shown by Figs. 4 to 7, we would have a steady ship in place of the oscillations recorded when all the tanks were in full operation and the plant itself is found to occupy between one-tenth and one-twentieth the space, the proportion being 1.5 to 21.7; the gyro plant weighing only 10 to 20 per cent of the tanks and contents. Again, this small space is practically independent of location. It need not occupy the most valuable amidship space nor extend entirely across the ship at point of greatest beam. It may even be divided up in two smaller spaces and stowed away at any point selected by the designer. In this way the small space required may be that which is least valuable in the whole ship. Again, the gyroscopic plant, unlike the tanks, is entirely independent of the height component of

location, as it is found to operate equally well in the lowest part of the ship and is entirely independent of symmetry as to disposition in relation to the ship's center of oscillation. The gyro precessions being under individual control, each is rendered effective with full force. The action is thus incessant with no intermissions, whereas the sea is not consistent, sometimes delivering and sometimes absorbing energy from the ship, as seen in the rolling diagrams. This persistent and incessant action, always in the right direction, not waiting for the period but working more rapidly than the period, constitutes another explanation of the smallness of the necessary plant. In modern ships of low M. G. it is found that the active gyro equipment will represent only a fraction of one per cent of the displacement.

The gyros were built with vacuum casings, as shown in Fig. 8, Plate 81.

Ordinary babbitted bearings with a new system of oil distribution were employed.

The gyro equipment of the Worden contains the most powerful plant thus far constructed and the first with the spinning axis lying in their natural position, namely, horizontal.

The spindle is of high tensile steel by the Midvale Company, hardened and ground, resting at its ends in journals contained in centers of two half-ring castings standing vertically in the figure; these are bolted together at top and bottom where they receive the vertical gudgeons and support the circular vacuum case in cast iron. The gudgeons on the vertical axis, one directly above and one directly below the gyro, are spherically seated bearings supplied with grease cups. The lower of these bearings is provided with a thrust for supporting the weight. Vacuum glands surround the shaft on each side as shown in Fig. 8. The wheels are spun by small induction motors with friction drive of about two inches in width. These drives are found to work with about one per cent slip only. At the base of the gyro is a four-foot combined cable and braking drum with the braking surface above.

The gyros were placed in A-shaped towers, as shown in Fig. 9, Plate 82, at either side upon the deck, amidships, and between them there is a small, twin-cylinder steering engine driving a cable drum, made by the Hyde Windless Company, of Bath, Me. This is shown in Fig. 12*a*, Plate 84; Fig. 12*b*, Plate 85; and Fig. 13, Plate 86.

This precession engine is provided with the usual control and reversing pilot valve. The crank pin discs are provided with brakes, the arrangement being such that the brakes are set when the pilot valve is in its central position, the brakes being immediately released when steam is again admitted to the cylinder in either direction. This engine was also provided with the usual automatic for preventing over-running in either direction. To the

cable drums of each gyro is secured a pair of cables connected direct to the cable drum upon the engine, so that by operating the engine the gyros can be turned slowly back and forth upon their vertical pivots by means of cables lying in grooves, plainly seen in Plate 86.

This oscillation constitutes the precession movements of the gyro, under constant and instant control in either direction.

CONTROL.

The arrangements for control are such that the precessional movements on the vertical axis could be either controlled by hand or automatically. The automatic control was through an auxiliary, magnetically operated pilot valve, similar for all purposes to the little gyroscopically controlled steering engine of the Whitehead torpedo.

AUTOMATIC CONTROL.

Several methods of automatic control have been investigated. Froude in 1873 developed an apparatus for simultaneously recording the rolling of vessels and the slope of the waves producing or contributing to such roll. In this apparatus lies a clue to one simple form of automatic control of the precessional movements of the gyros so as to measurably forecast or anticipate the rolling of the vessel.

A method, however, has been discovered of combining Froude's short and long pendulum in one comparatively simple apparatus and also greatly increasing the length of the long pendulum, as well as very materially augmenting its mass moment. This control is based upon the peculiar arrangement of two small gyroscopes weighing about ten pounds, and the pendulum so obtained represents a mass approaching half a ton with a pendulous length of ten miles. The control thus constituted has been finally brought to the point where it responds to only one component of universal angular motion. That is, it is not in the least affected by any amount of pitching of the ship or angles of yawing or azimuth or other movements. A close view of the apparatus is shown in Fig. 11, Plate 83. As indicated by results, this simple control apparatus causes the gyros to instantly neutralize the direct effect of all sea impulses, as elsewhere more fully described. An eminent essential of such control apparatus is that it shall be independent of period and that it shall be free from any liability to harmonize with any periodic motion of the ship. The operation of the device indicated that it successfully fulfils all these conditions.

One important feature of the active type of gyro is its power to artificially roll the ship on which it is mounted.

This feature is of great value when applied to ships in icebound waters, inasmuch as it enables them to keep free of the ice. In the case of the S. S. Ashtabula, we have a ship of about 5,000 tons displacement plying regularly between ports of this country and Canada across Lake Erie. Her general dimensions are as follows: Length, 370 feet; beam, 56 feet; displacement loaded, 4,500 tons; draught, 11 feet; period, from 5.5 to 6.6 seconds. In stormy weather she has rolled in the neighborhood of 35 degrees or through a 70-degree arc. In this instance and on Lake Erie this rolling is usually due to a succession of comparatively small increments, the magnitude of which has been ascertained.

In Fig. 14, Plate 87, and Fig. 15, Plate 88, are shown an active gyro and damping tanks of equivalent stabilizing power which have been carefully calculated from known formulæ, the analyses of which have been brought to conform exactly to the formulæ of Herr Frahm. These formulæ have also been used in the diagrammatic analysis. The metric system has been used throughout to facilitate the comparison. The period of this ship varies from 5.6 to 6 seconds according to the number, weight and distribution of railway cars upon her four tracks. The total net load capacity of this vessel is about 1,500 tons. The tanks in each instance have been designed for taking care of one-degree wave slope increment. Since the trips are of comparatively short duration and the load varies through quite a large range, the adjustment of the tanks would be imperative to bring them into synchronism. There would be no reserve quenching power available in the tanks shown, the free space necessarily being small. There being no available space above the main deck for the tanks, they are placed below.

Keeping the characteristic displacement × period × M. G. constant, we have the following results as to tanks and gyro:—

COMPARISON—DAMPING TANKS AND EQUIVALENT GYRO STABILIZING PLANT, S. S. ASHTABULA.

Period of roll.	Notes.	Weights in metric tons.			Percentage of displacement.	Space required.		Capacity for rolling ships.
		Water.	Tanks.	Total.				
Tanks.								
						cu. mtrs.	*cu. ft.*	
6 sec.....	Two tanks 60 feet and 40 feet long.	784	95	897	19.8	960	33,180	None.
6.6 sec.....	Two tanks 40 feet and 20 feet long.	490	65	555	12.4	626	21,600	None.
Complete gyro equipment.								
Any period...	One plant.	0	0	51	1.1	64	2,200	Through an arc of 8° to 10°.

Even with these tanks it is doubtful whether sufficient resonance can be developed during the time when the boat has less than a 6-second period in the one case, or 6.6 seconds in the other.

In the Ashtabula extreme space requirements are not of great importance but the extra weight of the tanks and water would probably interfere with the boat's clearing the bar on the Canadian side. In Fig. 14, Plate 87, the tanks for the 6.6-second roll are shown, together with the diagrammatic analysis of their action, and there is also given a scale outline of a single gyro which will yield much more than the equivalent stabilization to the boat, with an extremely low maximum stress of the wheel, the gyro in its action being entirely independent of the period of the boat.

Figure 15, Plate 88, shows tanks having the same damping factor, namely, one degree of wave slope, for a 6-second period of the Ashtabula. The extreme size and weight of these tanks are apparent and they stand out in still greater contrast to the gyro equipment.

Again we find that the gyro is quite elastic as to design and can be made smaller and broader, wide or narrow, to fit spaces available. The weights given are for all parts, including foundations, strengthening and bracing, and the space requirements are outside of that actually used.

The very low maximum stress of only 6,250 pounds per square inch is present in this wheel and this at only one point in the wheel.

Should we select a larger maximum stress for the wheel, then the gyro plant is considerably decreased over the above figures. This wheel can easily be made to give nearly double the roll quenching power.

Even in this extremely stiff ship, requiring relatively an unusually heavy gyro, the differential as to both weight and space stands out in favor of the gyro in marked contrast to the tanks. This is especially true when it is understood that the tanks will only function or perform half, and the more unimportant half, of the work easily performed by the gyro; that is, the tanks are only serviceable for stabilizing, whereas the gyro is originally intended for producing roll in the ship to prevent the ship from being caught in the ice or freezing solid in the process of forcing her way through heavy ice fields and especially wind row ice during the winter and spring months. For this latter purpose, however, it is found that a small gyro will perform all those functions, that is, the gyro illustrated here, while ample for stabilizing the ship, is much larger than is required for rolling. The gyro illustrated would only require to be run at one-third or one-half speed for the production of all the rolling that could ever be required by the Ashtabula in breaking through the heaviest ice. This is owing to its incessant action developing its full force in proper direction and with the proper emplacement upon each half period. Very heavy rolling can easily be produced and maintained. The action under these conditions is far simpler than in preventing roll, inasmuch as the reaction of the ship after rolling has started is found to react back to the gyro sufficiently to automatically control its precessional movements; usually in rolling only fractional speeds of the gyro are used.

Not the least interesting in connection with the Worden equipment were some gyroscopic pendulums employed in obtaining records of the motions of the Worden. These recorders were originally designed by the author to represent pendulums (though they are actually less than a foot in height) of very great pendulous length, namely, 1,000 miles, representing an artificial mass moment of $1\frac{1}{2}$ tons hung from the distance. In the earlier trials of this instrument it was found that there existed no necessity for so long a pendulum and this was afterwards reduced to the equivalent of a ten-mile pendulum. The records were obtained by the gyros thus arranged. In connection with this apparatus one point which is new and is of special interest is the elimination in the records of the influence of extraneous motion components reaching the instrument or influencing to the slightest extent the record itself.

For instance, if we are recording the roll of the ship it is desirable that all motions relating to either the pitch or yaw or other azimuth movements should be eliminated and the apparatus be entirely free from disturbances

from these or any other motions which do not represent the proper roll component. Two views of this apparatus are shown in Fig. 16, Plate 89, and Fig. 17, Plate 90.

Figure 18, Plate 91, and Fig. 19, Plate 92, show in plan and also in elevation similar gyroscopic recording apparatus for the U. S. Navy, upon which six records are made on a single tape. These are as follows:—Curves indicating both roll and pitch, means for spotting either, the base line, timing and means for drawing a curve indicating the simultaneous azimuth of the ship's heading relative to any desired fixed line, as the meridian, the running of the sea, direction of wind, etc., etc.

Universal or compound angular motion may be said to be made up of three primary components similar to the three primary components of white light and probably from the same basal cause; thus universal angular motion may be resolved into motion about three axes, all normal to each other and bearing the relation of the three converging margins of a cube. Gyroscopes mounted for producing motion records, so far as has been heretofore published, are in each case critical to all of the three above named components. In this manner the rolling record is liable to be falsified by motions which really have their origin in yawing, or pitching, or both. Suffice it to say that a mounting has been finally adopted by means of which any two of the three components are entirely eliminated and prevented from influencing the records, which are thus confined to any single component of motion that may be desired. At the same time the natural period of the apparatus is made so long as to be entirely removed from any influences of the comparatively short periods of motion to the ship itself. In this manner, a base line of extreme rigidity has been created about which all of the ship's motions take place and which is sensitive and critical to only one selective component of such motions, it having been found possible to record the most minute motions of the ship in this selected plane. For instance, upon one occasion distinct record was made on the Worden, when her displacement was about 700 tons, of two men walking from one beam to the other, indicating about four minutes of arc upon the record.

Through the important work to which only brief reference has here been possible, knowledge of the performance of the stabilizing gyro under service conditions has been accumulated. This is now such as to enable us to calculate with all necessary accuracy the weight and space occupied in connection with practically any plant, either stabilizing or ice-breaking; also to predict with certainty what the result will be, the amount of power required and also to prescribe with fair degree of accuracy about what will be the stabilizing or rolling factor upon any given ship with the new active gyros fitted.

THE CHAIRMAN:—The morning hour for adjournment having passed, we will now adjourn. The meeting will reconvene at 2.30. At 2.15 there will be a meeting of the Members of the Council.

The discussion on Mr. Sperry's paper, which has just been presented, as well as that on the paper by Mr. Gillmor, we expect to take up immediately after the opening of the afternoon session.

The meeting then adjourned.

FRIDAY AFTERNOON, NOVEMBER 22, 1912.

President Taylor called the meeting to order at 2.45 o'clock.

THE PRESIDENT:—I am very glad to say that the Society at the banquet to-night will have, with the possible exception of last year, when we were joined with two or three other societies, the largest attendance we have had at any banquet of the Society. I think you will be interested and I hope as many as possible will be present.

The Secretary will now advise you of the action of the Council on the additional election of Members.

THE SECRETARY:—The Council elected Naval Constructor R. H. Robinson to fill the vacancy in the Council caused by the promotion of Mr. Lewis Nixon.

The Council also passed favorably on the following applications (the Secretary read a list of applicants).

ELECTIONS TO MEMBERSHIP.

Members.

Erwin Chase, Chief Draughtsman, Electric Launch Co., Bayonne, N. J.

George E. Burd, Captain, U. S. N., Engineer Officer, Navy Yard, New York, N. Y.

William H. Raab, Solicitor, Robins Dry Dock & Repair Co., 15 Whitehall Street, New York, N. Y.

Captain H. M. Seeley, U. S. Supervising Inspector of Steam Vessels, 701 Custom House, New York, N. Y.

William J. A. London, Chief Engineer, Terry Steam Turbine Co., Hartford, Conn.

Thomas Benson, Chief Engineer, Floating Equipment Baltimore, Chesapeake & Atlantic Railway Co., Pier 1, Pratt Street, Baltimore, Md.

Charles S. Gawthrop, District Manager, American Car and Foundry Co., Wilmington, Del.

Associates.

Newman Page, Draughtsman in Charge, Mechanical Department, Electric Boat Co., Groton, Conn.

John Winslow, Chief Progress Man, Inspection Department, Navy Yard, New York, N. Y.

Stevenson Peirce Taylor, 123 West 85th Street, New York, N. Y.

Juniors.

Joseph J. Kam, Draughtsman, Electric Boat Co., Groton, Conn.

Albert Hoersch, Hull Draughtsman, Electric Boat Co., Groton, Conn.

Walter D. Allen, Computer, Electric Boat Co., Groton, Conn.

Revere B. Pulsifer, Assistant in Naval Architecture, Massachusetts Institute of Technology, Boston, Mass.

THE PRESIDENT:—You have heard the elections approved by the Council. Those in favor of adopting the report will say Aye; opposed, No. Unanimously carried, and the gentlemen are hereby declared elected—Mr. Robinson a member of the Council, and the others in their respective grades.

DISCUSSION.

THE PRESIDENT:—The next thing in order is the discussion on the paper entitled "Active Type of Stabilizing Gyro," by Mr. Elmer A. Sperry. Is there any discussion on that paper?

MR. RUDOLF BLOHM, *Visitor:*—If I ask your kind permission to say a few words on the paper of Mr. Sperry, I must at the same time apologize for not being able to deal with some of the points as thoroughly as I should like. I had no opportunity to study the paper before it was read, so I am able to speak on that part of the paper only which Mr. Sperry read in his abbreviated extract; and not having had time to collect the necessary data, I shall not now attempt to compare the different devices for damping the rolling movements of a ship, as to effectiveness, weights, spaces occupied, and so on. The object of my speaking is to call your attention to some facts mentioned by Mr. Sperry concerning the theory of rolling.

Dealing with the question of primary resonance between waves and ship, Mr. Sperry said:—"There is no such thing as resonance between waves and ship," and from this statement draws the conclusion that any anti-rolling device, relying for its effectiveness on the existence of secondary and artificial resonance, will not

dampen in the ordinary sea conditions. Even if we assume that there will be heavy rolling of the ship without resonance between the periods of the waves and the period of the ship, this, of course, would only be true if the ship itself should not retain its individual rolling period, to which the period of the water in the tanks has been adjusted. As soon as it is proved that the ship always has the same or nearly the same period, the effectiveness of the tanks would not be affected by the absence of the primary resonance between waves and ship. Now on page 201 Mr. Sperry doubts the fact of a constant rolling period of the ship, saying that he noted a change of 30 per cent between the period of a ship at 15 knots and at 0 knots, but he does not say anything on the law governing the dependence of the rolling period upon the speed. Similar doubts were uttered during the discussion before the English Institution of Naval Architects in 1911, which dealt very largely with these questions, and from which Mr. Sperry quotes at different times in his paper. At the end of the discussion, Herr Frahm said:—"I have had before me quite a number of rolling diagrams recorded on board of all sorts of ships, tender and stiff, which proved the correctness of my assertion (as to ships rolling only in their individual period). In fact all these ships, the displacement of which varies from 1,200 to 30,000 tons, when rolling considerably have always maintained their individual period, and only trifling differences, which rarely came to more than five per cent, have been observed." There may be considerable differences, however, in the period of the waves, in resonance with the period of the ship. This may easily be seen when considering that the ship, steaming against the waves at a certain angle, receives more impulses from waves of a certain period than a ship struck by oblique waves of the same period coming up from behind. In both cases, however, the period of the ship remains the same, and the tanks therefore will be effective.

If Mr. Sperry denies the existence of primary resonance, there is still another question to be considered:—Is the ship rolling at all to a considerable amount if there is no resonance between the waves and ship? Since the ship as a whole is rolling in exactly the same way as an ordinary pendulum, the simple, well-known experiment of the double pendulum will prove to you that there will be no heavy rolling if there is no primary resonance between waves and ship. In this experiment the second pendulum is only swinging heavily if it has the same period as the first pendulum from which it receives the impulses. The second pendulum will make small, irregular oscillations only, in both cases, if its period is shorter or longer than that of the first pendulum. During the reading of his papers before the German Schiffbautechnische Gesellschaft, 1910; the English Institution of Naval Architects, 1911; Herr Frahm showed an experiment in attaching a third pendulum to the second, the first pendulum, which received regular impulses, now representing waves of a given period, the second representing the ship and the third the water in the tanks. By changing the length of the second and of the third pendulum and thus establishing conditions of resonance of shorter or of longer periods of the ship and of the tank water, Herr Frahm clearly showed that all

oscillations not caused by resonance are of a very small amount only. This has been confirmed by rolling diagrams taken from tank experiments as well as from a great number of ships. On Plate 17 of his above-mentioned paper, Herr Frahm has published curves from tank experiments, showing the behavior of a ship when struck by quite irregular impulses, their period varying from 5 to 11. The diagrams taken on board ships also show that forced oscillations of ships caused by waves of a different period make the ship swing quite irregularly, but do not produce heeling amplitudes comparable to those of natural rolling. Even on smaller vessels these amplitudes scarcely amounted to more than 5 or 6 degrees. The conclusion to be drawn is that any anti-rolling device has to be designed ONLY for the case of resonance. I think there is a discrepancy in Mr. Sperry's paper concerning the question of resonance. If he doubts the effectiveness of tanks in "instances only slightly removed from synchronism," why then does he assume heavy rolling of a ship if "there is no such thing as resonance between waves and ship?"

To prove his statements of the ineffectiveness of the tanks upon conditions where the sea is out of synchronism with the period of the ship, Mr. Sperry takes the curves on Plate 80 of his paper. I think these curves, showing the rolling amplitude of the ship for a very few minutes only, extend over a time much too short to give a fair view of the usefulness of the tanks. The original curves from which Mr. Sperry has taken the curves shown on Plate 80 are published in Herr Frahm's paper and extend over a period of several hours for each instance. Moreover, they are taken at different loading conditions of the two sister ships Ypiranga and Corcovado, which, of course, affect the period of the ship. The periods indeed vary from 3.73 to 4.61 oscillations per minute in the case of the Ypiranga, and diagrams taken for different periods of the ship prove that the great usefulness of the tanks is not considerably affected by the change in the period of the ship. The reduction of the amplitudes is in one instance from 11 degrees to $2\frac{1}{2}$ to 2 degrees, in another instance from 18 degrees to 4 to 3 degrees, and with only one tank in action from 18 degrees to 7 degrees, which is much more than in the curves on Plate 80 of Mr. Sperry's paper. Since some of Herr Frahm's diagrams have been taken in a very heavy sea gale, I think Mr. Sperry's assertion that "the percentage of the departure where they fail grows smaller and smaller as the sea grows heavier," is not justified, and I am sorry Mr. Sperry did not publish any data or curves to prove his words, "We find that the tanks have already practically failed to perform any useful function whatever." Since the time of the publication of Herr Frahm's paper, rolling diagrams have been taken on a great number of ships, all of them showing a very large reduction in the heeling amplitudes, though the tanks have never again been placed as high as in the case of the Corcovado and the Ypiranga. In the Kaiserin Auguste Victoria of the Hamburg-American line, for instance, the rolling amplitudes in a very heavy storm were reduced to 33 per cent of their amount when the tanks were not in action. This is no specially selected example, but one which just occurs to me.

As to Mr. Sperry's words on page 201 that "it is sufficient to say that experience has demonstrated that damping tanks are disadvantageous, if not positively dangerous, when out of synchronism," I want to say that it is a special feature of the new devices of anti-rolling tanks that they are fitted with an air pipe, connecting the tanks on both sides of the ship, and that this pipe has a valve which may be closed. In this case there will be no free water surface, as in the earlier anti-rolling devices of Sir Philip Watts, Professor Biles and others, where the water was allowed to rush through from one side of the ship to the other. In the Frahm tanks the movement of the water can at any moment be controlled by blocking the air connections and, by throttling the air, the oscillations of the water may be adjusted to the conditions of the sea. So there is positively no danger connected with the water in the tanks. I think the best proof concerning the reliability of anti-rolling tanks is the fact that the Hamburg-American line has already installed, or is installing, the Frahm tanks into all of its big ships, including the Imperator and her two sister ships of 55,000 tons each, and nearly all other important German lines running passenger steamers are doing the same.

The Cunard line also is installing the tanks into its latest and biggest ship, the Aquitania, after having given them a thorough trial in the Laconia, commissioned last year. In fact, the sum of the displacements of ships in service or under construction, fitted with Frahm anti-rolling tanks, now amounts to 551,200 tons. I do not think that the responsible men of all these companies would take the risk of installing the tanks, if there were any danger connected with them.

Mr. Maxwell W. Day, *Associate* (Communicated):—In paragraph (*c*) on page 198, Mr. Sperry has stated that the use of the gyroscope saves power in propelling the vessel on account of the elimination of rolling. It would be interesting to know how much less power is required to propel a vessel in rough water when it is maintained steady by the gyroscope than when allowed to roll freely.

Also, he mentions the longer period of the roll of the vessel when steaming as compared to the period when not under way. It would be interesting to know how much longer this period is and what is the reason for it.

Mr. Carl L. Norden, M. E., M. S. M. E. (Communicated):—I have read with great interest Mr. Sperry's paper on a subject to which I have given much time. I have also read the discussion of Mr. Rudolf Blohm. I beg to add a few words regarding the new stabilizer and its quite remarkable performance.

First, with regard to Mr. Blohm's conclusion "that any anti-rolling must be designed for the case of resonance." This may be based on the assumption that such a device is only required to reduce excessive rolling, which, as we all know, happens when a vessel receives a series of strong impulses somewhat in phase with its own natural period. Mr. Sperry's conception of true stabilization is an entirely different one. With Sir Thornycroft, he believes, on the contrary, that a stabilizer should exert upon the ship, at all times and up to its rated capacity,

moments that are equal and opposite to those due to any wave impulse or any outside disturbing cause. Although the mass moment of the ship is useful in evening-up small differences between the acting moments, he proposes to deal in principle with each impulse separately.

Suppose a vessel is kept very close to its natural upright position, say within a degree or so, it is evident that its momentary angular velocity, respecting its variation, will be the result of the algebraic sum of all the moments that act upon it, including the ship's small righting moment. Now if an active stabilizer, for instance Mr. Sperry's gyro, is precessed with positive control in such a way that this angular velocity of roll remains practically zero, the ship will be held within very small angles; these angles will, in fact, be only such as are necessitated by the particular type of control employed, and this condition is easily maintained up to the maximum capacity of the stabilizer as against any wave impulse.

To illustrate further the unique operation of Mr. Sperry's stabilizer, it would be as though we were to effect stabilization by a non-pendulous gyro of the passive type but possessed of no precession inertia, no suspension friction; in a word, practically nascent yet with its full stabilizing and centering instinct, exerting stabilizing couples precisely as required. One of the most interesting and significant points in this connection is that under these conditions there is practically no work done by the ship upon the gyro or by the gyro upon the ship because of there being practically no angular velocity present. It is this fact, taken together with its incessant operation, working, as Mr. Sperry states, much more often than the half-period of the ship, that accounts for the smallness of the plant required.

Much time has been devoted to arriving at the efficiency of these stabilizers. Starting with a theorem laid down by Naval Constructor David W. Taylor, U. S. N., it has been determined that the efficiency of the stabilizer operating as described above is very close to 100 per cent.

Should some individual wave moment attack the ship which is of a magnitude above the capacity of the stabilizing plant, its specific quenching efficiency still remains very high, because:—

1. Its roll-quenching impulses are always given when the ship's small angular velocity is approximately at its maximum, thus avoiding the inefficient part of the cycle of a pendulous stabilizer, even when in phase with both the ship and sea. It is known that the pendulous stabilizer could never exceed about 70 per cent efficiency and usually much less, because in practice it could never rise to—

$$\int_0^{\pi} \sin^2 a da$$

2. Its moments are always applied with a maximum efficiency in the right direction, and perfectly in phase with the ship in a mixed sea. A pendulous stabilizer does not satisfy any part of this requirement.

3. The cycle of wave impulses such as is shown in the first figures of this paper affords really two points in each cycle at which the stabilizer will always bring the ship upright, so that each new set of wave impulses between these points

will always be met by the maximum mass moment against rolling, whereas a stabilizer based on resonance and itself possessing very large inertia will keep on rolling the ship.

The inertia of a pendulous damping mass can be destroyed quickly enough, but this should always be done at such a rate as to maintain its period, and its mass must then be re-energized by the ship at the cost of further rolling.

If we consider a typical roll record, taken when the ship approximates periodic resonance with the waves, we observe that the rolling is made up of individual groups. The more regular the sea, and the more the apparent wave period equals the period of the vessel, the greater the number of individual rolls constituting a group, and, to a certain extent, the greater the amplitude of unrestricted rolling reached. To ascertain the magnitude and character of the wave impulses a given stabilizer would have to deal with in keeping the ship upright, one has to augment the angles of roll recorded by the friction-damping angles for each single roll. The latter angles are available from a natural dying-down record, taken at the same steaming speed, and will be found surprisingly large where higher speeds and effective bilge keels are present. It will also be observed that each group represents two sets of wave impulses with some small impulses between them where the ship is completely out of phase with the waves. The new non-resonance type of stabilizer of Mr. Sperry is always in perfect tune with any impulse and is found to enjoy twice as many "breathing spells" as would seem apparent from the roll diagram, whereas a resonance device in the same sea will find between the decreasing and increasing portions of the record a lapse in phase between the sea and the ship, causing the pendulous mass either to give not enough or too much counter moment, often actually producing roll. Its low specific quenching capacity is, therefore, the very result of the resonance principle employed, and due to the fact that only during an occasional roll increment it develops moments that are in phase with and of the same magnitude as those received from the sea.

Rear Admiral Bradley A. Fiske, *Commander 1st Division U. S. Atlantic Fleet* (Communicated):—I have read the paper by Mr. Elmer A. Sperry, called "Active Type of Stabilizing Gyro," with great interest and pleasure. What Mr. Sperry has accomplished already is most remarkable; and even if he does not succeed in accomplishing everything that he is attempting, it seems sure that he will accomplish enough to make him a benefactor of all "who go down to the sea in ships."

Whether Mr. Sperry will succeed in accomplishing all the great things that he is attempting, I am, of course, unable to predict; but it is certain that it would be extremely desirable that he should succeed, and therefore that he should be given all possible encouragement.

I have also glanced over the paper of Mr. Gillmor, called "The Sperry Gyro-Compass in Service." Mr. Sperry's gyroscope compasses are fitted in the Florida, and I am glad of the opportunity of testifying to their great efficiency for the pur-

poses intended, and their value in naval work. Mr. Gillmor is very optimistic, but in my opinion he is not too optimistic.

Mr. F. L. Du Bosque, *Member of Council* (Communicated):—The discovery by Mr. Sperry of a device that will prevent the rolling of ships at sea, which this paper really shows, comes to us with such suddenness and surprise that its effect is not fully realized.

It seems to me that Mr. Sperry has discovered a new force in so far as its effect upon ships is concerned. The earth's motion and the motion of the heavenly bodies have a precessional movement in the path of their orbits, and a force in a horizontal direction similar to this is exerted by the gyroscope when rotated on a horizontal axis. The amount of the force is dependent upon the speed and weight of the gyroscope and the direction in the horizontal plane is easily controlled.

Mr. Sperry has determined by experiment and calculation the force exerted by this precessional movement of the gyroscope and is able to decide the size of machine and the speed of rotation required to produce any precessional force. It can easily be conceived, therefore, that when the force required to list a vessel to any degree is known, it is possible to install the proper type of gyroscope to prevent this listing action. It must be borne in mind, of course, that the movement of the gyroscope to prevent listing must anticipate the listing action and its direction, and Mr. Sperry proposes to accomplish this by installing a very sensitive gyroscope pendulum that, acting on suitable devices, cause the main gyroscope to slowly oscillate on its vertical axis in the proper direction at the instant the vessel heels to the slightest degree. It is not likely, therefore, that a vessel can be maintained in a constant upright position, but undoubtedly the angle of heel will be very small and not sufficient to cause annoyance to passengers. In this respect the gyroscope is undoubtedly superior to rolling tanks that have been experimented with considerably in the past, and it seems to me that the author of the paper has, in a practical and commercially possible way, provided the long-sought-for device that will prevent the annoying rolling of ships.

Mr. Sperry (Communicated):—I wish to congratulate both Mr. Frahm and Messrs. Blohm & Voss, who are the owners of the Frahm damping tanks, upon the favor with which their installations have been received. I look upon this effort to damp out part of the rolling of ships, even reducing it to 33 per cent, as Mr. Blohm states at one point in his discussion, as being in the right direction. I believe that our German contemporaries are doing excellent missionary work in educating the public in the use of ships that roll much less than heretofore, and toward ships that in the future will be entirely free from rolling. The full scale trials that have been prosecuted during the present year have ushered in a new era wherein ships will be entirely free from rolling.

The tanks Mr. Blohm refers to in his discussion are for the purpose of reducing the rolling, or suppressing it in part, whereas the active type of gyroscope described

in my paper is for the purpose of completing this good work to the extent of the entire prevention of rolling—instead of dealing with it in part it deals with it in whole.

With the new arrangement, the great longitudinal stability of the ship, which is always present, can be laid hold upon and utilized athwartship to any extent desired, not merely for the reduction and suppression but for the absolute prevention of rolling, up to and including any wave increment or wave slope impinging the ship. In fact the active gyro never operates in any other way; the ship never responds to the wave slopes or any of the incessant wave actions; and never rolls until the limit originally determined upon has been exceeded, and then the motion amounts to only the small overplus or excess existing in some exceptional wave increment which on the next half oscillation of the gyro is wiped out.

It has been definitely ascertained, as has been well stated by a member of our Council, Mr. F. L. DuBosque, in his kind words of discussion on this paper, that at last we have in hand "the long-sought-for device that will prevent the annoying rolling of ships."

Dealing with primary resonance, Mr. Blohm's statement that "As soon as it is proved that the ship always has the same or nearly the same period, the effectiveness of the tanks would not be affected by the absence of the primary resonance between waves and ship," seems to indicate that it is his belief that, so long as the ship retains her period, the effectiveness of the tanks is unimpaired and remains independent of the period of the sea with any given sea intensity.

In answer to this I would call attention to Figs. 4 to 7, Plate 80, where the tanks which were effective under the four quite widely differing conditions as to intensity of sea when same was synchronous, have, as we see, become practically useless; nothing has changed except the period of the sea or the primary resonance between waves and ship, and this only slightly. Here is a case taken from Frahm's own work, fully corroborated by work on this side, which conforms to Mr. Blohm's requirement that the ship shall retain its period, and yet the tanks have practically gone out of business from no other cause than a slight change in the period of the sea.

Mr. Blohm's statement that the period of a ship varies with change of load from 3.73 to 4.61 indicates a change of approximately 30 per cent, about the same as has been observed upon a tender ship rolling in still water and when steaming.

I am glad Mr. Blohm mentioned the compound pendulum. All who are familiar with this interesting mechanism know how entirely inoperative it is, unless quite exact synchronism is maintained throughout the entire chain of pendulums. Work with this compound pendulum is very instructive and serves to show most emphatically how utterly circumscribed and limited is the usefulness of any device tied down to a single period, especially in preventing motions of mixed periodic origin. The pendulum always responds with perfect freedom to the first impulses; later, often too late, the secondary pendulum or pendulums get under motion and oppose to a certain extent further increment in the main pendulum, but by this time the original impressed force has perhaps changed its period and the secondary

pendulum may then actually be found to be increasing the motion instead of decreasing it as expected. This very phenomenon has been observed at sea with tanks and, when repeated in period, renders them positively dangerous, as stated in my paper.

Work with a compound pendulum, especially when truthfully representing, as far as possible, sea conditions as to original energizing impacts, shows in the most emphatic manner the necessity for breaking away from devices limited to resonance or periodic phenomena. On the contrary, the device to be effective must not be tangled up with some past happening that has excited it, but should be free to grapple and fully deal with each present disturbance and so neutralize it that no motion of the pendulum or ship can result; and then deal with the next, and the next, independent of their direction, time or intensity. If no individual impact is permitted to move the ship, the ship never begins to move and therefore remains motion-free.

Referring again to Figs. 4 to 7, Plate 80, we are informed that these tests extended over several hours. What is more important, we know, as stated above, that they are absolutely representative of the several conditions. We also know that with heavier sea conditions the percentage of departure from synchronism when the tanks fail is smaller than on light seas. Compare this percentage in Fig. 7, Plate 80, with that of the other figures on Plate 80. Mr. Blohm mentions that the above facts with regard to heavier seas "are not justified." He also stated that "he (Sperry) has not published any data or curves to prove his words." I ask: What further proof is required? If Mr. Blohm considers the performance in, say Fig. 7, Plate 80, where all the tanks were in full operation as useful stabilization, I for one certainly take issue with him, and will add that it has been definitely ascertained that there are sea conditions where the ship is actually obsessed with more total motion with the tanks in operation than when they are out of operation.

It is of course understood that the air line is used to render the tanks inactive at will, or when they become dangerous. The difficulty is that the remedy comes too late, and a complete closure of the air line locks the water on a listed boat so as to maintain the list. Considerable adjustment and attention would be required to keep the period of the tanks in harmony with that of the vessel, which Mr. Blohm states has been found to vary nearly 30 per cent from different loading, and also from changes in period due to different steaming velocities, especially in case of a tender ship, as stated in my paper.

It is also important that our stabilizer shall deal with the most aggravated and mixed seas, because they are almost universal and also because they are most vigorous and most disturbing; probably because such seas are entirely outside the practical scope of tank operation, Mr. Blohm tells us that they are unimportant and with characteristic Teutonic directness and finality we are informed "that any anti-rolling device has to be designed ONLY for the case of resonance." The emphasis upon the ONLY is Mr. Blohm's.

Improved and more perfect methods will always prevail. Improved methods

are now at hand which I predict will supersede damping tanks, fettered to resonance and period as they are, and also to disturbing the center of gravity of the ship and shifting same through quite wide limits; especially now that the new method, operating without altering the center of gravity to the slightest degree, is known to give superior results in any sea with far less weight and occupying only a portion of the space. This system operates entirely automatically, even when imparting roll to the ship, requiring practically no supervision, not requiring to be especially adjusted as do tanks to the period of the ship, or readjusted as the period changes.

With reference to the discussion by Admiral Fiske, I deem it fortunate that the flagship Florida should have come to this port at the time the ship undergoing trials with the active type of gyro was making tests alongside. It is gratifying that a device so new as this could have been reviewed in detail by such an eminent scientific and naval authority as Admiral Fiske, and that he could have witnessed something of its operation and its powers in controlling the ship.

At the time the proposition for trial of this new auxiliary was originally brought before the General Board of the United States Navy, Admiral Fiske was a member of this board. I wish here to express my appreciation of the liberal and progressive action taken by that board which led to the extended trials of the apparatus.

The Admiral's kind words of encouragement are much appreciated.

With reference to Mr. DuBosque's discussion, I wish to say that Mr. DuBosque approached the new apparatus from the standpoint of a man in charge of large and widely diversified shipping interests; he reviewed the device and its performance from the eminently practical viewpoint of whether the mechanism was likely to be useful and available under the conditions of every-day service of commercial shipping; his interest in the device was also from the standpoint of availability for ice breakers in the Great Lakes.

I much appreciate the permission of the Navy Department for Mr. DuBosque's inspection of the plant. It must be understood, of course, that he saw the first apparatus of this type ever built. We have learned much from its practical operation, including as it does 160,000 power precessions, and Mr. DuBosque has been good enough to suggest certain simplifications, of which I wish here to make acknowledgment.

In answer to Mr. Maxwell W. Day's questions, I have appended one sheet of curves which may be considered as Figs. 20, 21 and 22, Plate 93. Figure 20 gives a curve of gyroscopic stabilization; the middle section indicates where the gyros were in operation with one form of control; the end sections indicate the sea running at the time. In Figs. 21 and 22 the ship was impressed with exactly the same forces, namely, three gyroscopic impulses, and then allowed to die down by the form line resistance, the only difference being that in the first the ship was standing still and under no headway, whereas in the second the ship was steaming at 15 knots. Both of these were taken at sea within two minutes of each other. I am not allowed to give any quantitative data at this time but I may say that the last two records are upon the same scale and will afford, in all probability, sufficient basis for working out approximate answers to Mr. Day's questions.

In Mr. Norden's discussion we are given a number of important facts on the general subject. He brings out the results of his investigations relating to efficiency of stabilizers and shows that the new device leaves very little to be desired on this important point. He also calls attention to a very important and significant features of this new system of stabilization, viz., that when the angular velocity of a ship is held down to practically o, practically o work is expended in holding it; in other words, when the ship is held practically free from rolling it has been found in practice and has been thoroughly demonstrated to require very little power to maintain this condition. This is an original proposition toward which I have been working and was first set forth and discussed by me a number of years ago, and though it may at first sight seem revolutionary it is nevertheless true, and being true it should work nothing short of a revolution in our methods of stabilizing ships, and it also emphasizes the fact that there now remains no reason why ships should roll at sea.

My acknowledgments are also due to Naval Constructor David W. Taylor and many of his brother officers who contributed largely to the success of the work; and also to Carl L. Norden, M. E., who has been actively associated on the work.

THE PRESIDENT:—I am sure you will all agree with me that the Society is indebted to, and now gives its thanks to Mr. Sperry for his paper on the Stabilizing Gyro.

We will now proceed to the paper entitled "Notes on Fuel Economy as Influenced by Ship Design," by Mr. E. H. Rigg, Member of the Society.

MR. E. H. RIGG, *Member:*—In view of the fact that the reading of papers is desired to be limited to a short briefing of them, in order that the discussion may be opened, I will read but a small résumé.

Mr. Rigg presented his paper, and after the reading of it said: "I should like to add that I have recently been very much interested in reading the report of a lecture given in London before the Royal United Service Institution on ships of the Monitor class, that is, ships with longitudinally corrugated sides. Of course I have no definite information on this subject, but from the reports of the lecture it appears that a reduction of 15 per cent indicated horse-power is claimed for these corrugated sides. I think this type of vessel should be added to the examples given in this paper, because here is most decided economy due to ship form.

NOTES ON FUEL ECONOMY AS INFLUENCED BY SHIP DESIGN.

By E. H. Rigg, Esq., Member.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

In recent years we have witnessed great progress in marine engineering; new types are striving for first place, each having its advantages and its advocates; geared turbines, oil and gas engines, electric transmission and other schemes, each offering economies of fuel and therefore lesser operating expenses.

The latest transactions of the technical societies concerned each contain papers bearing on the subject, especially that read before the Northeast Coast Institution last April and that on the geared turbines on the channel steamer Normannia read before the Institution of Naval Architects this year, to say nothing of many important papers read elsewhere.

These all point out the possibilities of economy from the point of view of machinery savings. It is the object of these notes to point out possible economies due to efficient ship design, because savings are being made by naval architects, as well as by marine engineers.

Cheapness of operation is one of the necessities for commercial success in a competitive age. The problem of evolving economical ship forms is an intricate one, and a study of the records of this society will show that much time and money have been spent in the pursuit of efficient forms, which is another way of saying economy.

Experimental tanks have been built in all the leading maritime countries, and commerce is slowly but surely beginning to reap the benefits. Not only has ship form come in for the attention it deserves, but we have lately witnessed renewed efforts to solve propeller problems, so necessary to keep up with the higher speeds of revolution demanded by the new types of propelling machinery.

It is at once evident that the naval service has reaped the greatest benefit of the study devoted to ship propulsion; perhaps this is only natural, the pioneer experimental tank in our country being the government one at Washington. That this tank pays is evidenced by the difference between the Connecticut trials and those of the Michigan. The average ship of the Connecticut class required 15,700 indicated horse-power for 18 knots, whereas the later design, of identical displacement and type of machinery, required

only 13,100 indicated horse-power for the same speed. This means that for 10,000 miles the saving in coal amounts to some 1,100 tons at 18 knots; this can be fairly credited to the experimental tank and its able staff.

Our destroyer designs are also good examples of efficient propulsion; the way in which the recent vessels have gone through their trials compared with those of twelve years ago needs no comment.

The best speed at which to run a merchant vessel is not a question that the builder has much to do with. The distance between ports, proportionate values of passenger and freight business, the nature of the cargo, mail-carrying requirements, character of the waters traversed, and the competition to be met are the prime factors in determining this speed. Once it has been decided upon, the builders should be allowed to settle the dimensions best suited to the speed and the work (passenger and freight accommodations) expected of the vessel. It is surprising how many vessels are run at unsuitable speeds, some unavoidably so on account of passenger accommodations; but the majority could well have been reconciled in the design stage as regards the dimensions, speed, capacity, stability, trim and deadweight.

When the owners decide on their real service speed, the builders should not be required to run a measured mile trial reaching a top speed out of all proportion to the service speed; it can only be done at a sacrifice of efficiency elsewhere, probably in the fineing of the ship and consequent reduction in carrying capacity.

In fast passenger liners the proper reconciling of speed and dimensions may very well spell success or failure to the whole venture; this should be recognized and some time devoted to preliminary design work and model tank tests. The preliminary work on the Mauretania designs furnishes a case in point. Why should not corresponding care and attention be devoted to less ambitious designs? That many owners are seeking to get the maximum out of their investment is evident when we consider the number of special types lately coming to the front, all designed with a view to the utmost efficiency in their particular line, not only for driving but more especially for cargo handling and storage.

The following examples have been collected from recent experience in general design work, with the hope that others will be brought forward in discussion by those whose daily experience has been along similar lines.

EXAMPLE NO. 1.

Advantage of model tank experiments on hull forms and of careful propeller design.

The data below can be vouched for, the two vessels being tried over the same course, Delaware Breakwater; both were deep load draught trials and progressive runs were made.

It will be noticed that the displacement of the larger vessel, the model of which was tried in the tank, is 46 per cent in excess of the smaller, and the power identical at cargo vessel speeds. The larger vessel would take even less power at sea than the smaller on account of size. The first vessel is an oil tanker and the second a U. S. naval collier of the Mars class.

The figures below speak for themselves:—

Item.	*Year of 1903.*	*Completion 1909.*
Length	360 ft. 0 in.	385 ft. 0 in.
Breadth	46 ft. 3 in.	53 ft. 0 in.
Draught	20 ft. 7 in.	24 ft. 8 in.
Displacement in tons	7,700	11,260
Block coefficient	.786	.784
Propulsion, system of	Single screw	Twin screw
I. H. P. for 10 knots	1,525	1,550
I. H. P. for 11 knots	2,125	2,100
I. H. P. for 11½ knots	2,500	2,400
I. H. P. for 12 knots	———	2,800
Deadweight carried in tons	5,000	7,400

EXAMPLE NO. 2.

An interesting case of extravagant design came up recently. A shipping firm had plans of an eleven-knot steamer built in Europe of the following general dimensions:—400′ 0″×52′ 0″×34′ 0″. They wanted a duplicate built here, but with machinery for ten knots only. The suggestion that the steel hull could be built 6 per cent cheaper to modified dimensions without affecting the coal bill was rather a shock to the prospective owners. The vessel as redesigned, with identical deadweight, draught and cargo capacity, worked out at 370′ 0″×54′ 6″×35′ 0″. The power worked out as follows:—

Item.	*400-ft. ship.*	*370-ft. ship.*
Skin E. H. P.	685	645
Residuary E. H. P.	365	405
Total	1,050	1,050

These are for ten knots in each case. In addition to less first cost, the shorter boat will be handier at sea, more easily taken care of as regards stability, and occupy less space at piers. There was no question of repeating an order.

EXAMPLE NO. 3.

In heavy bulk carriers it is desirable to know how full a vessel can be made, keeping capacity down and so having no more ship than is necessary. A majority of ship designs on this coast are prepared for light cargoes occupying large space, where ship dimensions run large per ton deadweight; hence the saving in ship dimensions possible when carrying ore, for instance, is apt to be overlooked.

These vessels are frequently run at only nine knots, even though they have some margin of power; the problem resolves itself into one of finding the range of dimensions where the total resistance remains constant, even though the component parts vary. In a design to carry 7,000 tons deadweight it was found practicable to increase block coefficient from .75 to .78 and reduce length from 360 to 340 feet for the same effective horse-power at nine knots; this represented a 5 per cent saving in steel hull. Beam and draught remained constant.

This problem and the preceding one are merely examples of searching for the economical limit of speed, on which subject a good deal has been published from time to time.

While the temptation to keep power down by fineing the ship is a strong one, especially when owners expect a very low coal per diem rate, ship designers should never allow the dimensions to run up beyond what this somewhat elusive economical limit requires.

EXAMPLE NO. 4.

Quadruple expansion machinery versus triple for long voyages.

The author recently had a very forcible example of the saving possible if quadruple expansion machinery were fitted in a cargo steamer designed to carry 7,000 tons of paying freight for a distance of 14,000 miles, oil burning. The figures came out as follows:—

Item.	*Quadruple.*	*Triple.*
Length	400 ft. 0 in.	410 ft. 0 in.
Breadth	53 ft. 0 in.	53 ft. 0 in.
Draught	27 ft. 0 in.	27 ft. 0 in.
Ship, tons	4,125	4,160
Cargo, tons	7,000	7,000
Oil, crew and water	1,900	2,200
Displacement	13,025	13,360
Speed, knots	11	11
I. H. P.	2,750	2,800
Savings per voyage	$2,500	——
Extra first cost	$10,000	——

It will be seen that the extra first cost is recovered in four voyages, and after that a steady gain per voyage is apparent. This is not strictly an example of economy due to ship form, but has been inserted as being perhaps of interest.

EXAMPLE NO. 5.

From the point of view of economy due to machinery, it can be shown that single-screw propulsion is cheaper than twin screw, the advantage of twin screw being in greater immunity from breakdown, a point by no means negligible in passenger and perishable cargo ships. This is well known to the members of the Society and is only mentioned to make the examples more complete. This refers to steamers of customary revolutions per minute; for the newly arriving motor ship of high revolutions per minute the case is different and needs further investigation.

EXAMPLE NO. 6.

Recently published photographs of our latest battleships in dry dock reveal a peculiar bulbous form of bow, the load water-line being narrowed and the displacement made up by filling out the lower water-lines. Experiments at the model tank in Washington show a material saving due to this form, the bow waves being naturally lessened by the fine upper water-lines.

The superintendent of one of our coastwise lines of steamers has had the courage to adopt this form of bow for a twelve-knot cargo steamer, in which a 3 per cent saving would mean a ton of coal per diem, a by no means negligible amount when figured in dollars per annum. It is to be hoped this will be realized in service.

I am indebted to Mr. Higgins of the Old Dominion Steamship Company for permission to produce the data of the vessel mentioned.

Figure 2, Plate 95, shows curves of cross sectional areas and of water-lines compared; Fig. 3, Plate 95, gives superposed body plans. It will be

seen that at 12 knots and at 2 feet trim by the stern, the normal running conditions, a saving of 9 per cent results in effective horse-power; careful calculations show that 6 per cent of this is due to the finer model, beam and draught both being more in the bulb-nosed ship, leaving 3 per cent due to the bulb.

EXAMPLE NO. 7.

It is well known that river steamers at certain speeds and in certain draughts of water create excessive waves, causing bad erosion of the banks, besides damage to shipping.

A firm of owners recently had conducted for them experiments with several models to see what could be done to reduce this wave under their operating conditions. The tank finally showed them the best lines on which to lay down the vessel for minimum wave-making, the speed being obtained with less power in addition. This also reduced the slowing up necessary to prevent damage to shipping along the banks. The top speed was obtained in deep, smooth water for less power with the model that gave best results in shoal water. The vessel is 410 feet long and of 8 feet draught.

In 20 feet of water a saving of some 5 per cent resulted at working speeds. At low and moderate speeds up to about 18 knots, the best model for shoal water was the worst in deep water, but this could well be ignored in a river steamer.

EXAMPLE NO. 8.

A sound steamer of wide beam relative to draught, having flared guards. The plans submitted for bids had a midship section shaped as in *A*, Fig. 1, Plate 94; whilst this is good for stability, it seems to be capable of considerable improvement from the point of view of the coal pile. Recognizing the necessity of keeping the same stability, section *B* was designed. At the expense of a 2 per cent increase in the shell and framing of the vessel, an 18 per cent saving can be made in the coal bill; in other words the improved lines would cut the power from about 2,750 to 2,250, indicated, at 16 knots on a deep-water mile trial. The vessel was 270 feet long and of some 2,250 tons displacement.

Anyone who keeps up to date with the transactions of this and kindred societies will know what valuable original research work has been placed on record during the last few years. These notes make no claim to originality, but merely attempt to show, from the point of view of the practical designer of ships, the results presented in another form by our fellow designers working at experimental tanks and in colleges along more purely scientific lines than are possible at a shipyard, where the contract delivery date generally places a strict limit on the amount of preliminary investigation possible before the design has to take concrete form in the mold loft and the shops.

DISCUSSION.

THE PRESIDENT:—The paper by Mr. Rigg on "Notes on Fuel Economy as Influenced by Ship Design," is now before you for discussion.

MR. MASON S. CHACE, *Life Member:*—I am very much interested in what Mr. Rigg has said, but I feel that the work done by the shipbuilder, the naval architect, and the engineer, is so closely associated and so overlaps that it is very hard for one of the trio to make any progress without either pushing or pulling the others along. I am sure we all agree that the data which has been obtained from experimental model tanks has been of the greatest benefit to all engaged in building ships. To-day few designs are made without using such data in one form or another, and we can thank the Froudes for giving us the law of comparison in such practical form that we can use it. In using the law of comparison to make deductions from model basin experiments we must not stretch the law too far. The members of this Society as a society of engineers—using the term "engineers" in its broadest sense, as opposed to a society of lawyers—believe that it is as bad to stretch a law too far as it is to break it. When we use large operative models, 30 to 40 feet long, as a step intermediate between the small model, 10 to 15 feet long, and the ship, we have more accurate data on which to base the performance of the ship than is obtained from the small model. The Cunard Company was undoubtedly well repaid for the expense of building the large operative model of the Mauretania and Lusitania by the accuracy of the results which were obtained. When we use small models and split hairs over the results based on their performance, we are likely to fall into error. So, also, when we take the results of ship trials, unless the trials have been carefully conducted and are really comparable, and draw too general conclusions from them, we are likely to fall seriously into error.

I agree with what Mr. Rigg has said as to how much naval architects have benefited by the knowledge obtained from model tank tests. We in this country are particularly indebted to Naval Constructor Taylor and the authorities of the Washington Experimental Model Basin. All of us who have experimented there have, I am quite sure, met with uniform courtesy on the part of those gentlemen. Naval Constructor Taylor has presented in the form of papers before this Society many of the results which he has obtained in his tank tests, and he has also written a book on "The Propulsion of Ships," in which he has made an analysis of the results obtained from a number of tank tests on a large series of models, which series of tests would be far too expensive for any individual experimenter to conduct. By means of contours of residuary resistance based on the results obtained from this series it is possible for those working within the limits of ratios of beam to depth, longitudinal coefficients and displacement-length coefficients, covered by the series, to very closely approximate the residuary resistance of the proposed

vessel. Unfortunately, this series does not include ships of all of the proportions which we may be called upon to design. I think that comparatively few models are taken to Washington by shipbuilders as preliminary designs, and the results of the tank tests of these models compared with the results of the standard series from which the contours of residuary resistance were derived, without finding that improvements have to be made in these models in order to obtain as good results as the standard series shows to be possible.

I accept every statement which Mr. Rigg has made, without taking exception to any of them, but would like to ask him for more data on some of the information he has put before us. I think it is of as much interest to the members of the Society to know why and how things are done as to know the simple fact they have been accomplished. I hope Mr. Rigg will be able to give us more information with regard to some of the interesting examples he has presented.

If we take Example No. 1, we see there two ships, one of which has a displacement 46 per cent in excess of the other, and we find that at a speed of 11.5 knots it takes practically the same power to drive these two ships. Of course, that is very striking—that you can drive with the same power 46 per cent more weight at the same speed. The question arises: Are these results given the results of model tank tests, or are they the combined results of model tank tests and actual trials? If so, were the trials of these ships run under the same conditions? Is the data, as far as it goes, strictly comparable—assuming that the results are absolutely correct, which I do assume? Although we have not the full data of these ships, if we look at the dimensions given, we find in the case of the oil tank ship, in the left-hand column, under the heading "1903," that the ratio of length to beam is 7.78, and we find in the case of the ship in the right-hand column, under the heading "1909," that this ratio is 7.26. That is not much difference. We find the ratio of beam to draught for the left-hand column ship is 2.245, and in the case of the right-hand column ship 2.146, in other words, the ship described as the better ship has a slightly smaller ratio of beam to depth. At the speed of 11.5 knots, at which these ships take practically the same power, the speed-length ratio $\frac{V}{\sqrt{L}}$ in the case of oil tanker class is .606, and in the case of the navy collier class is .586; that is to say, the speeds at which these two vessels are run in proportion to their lengths are practically the same. The block coefficients of these two vessels are almost identical. The ship described as the poorer one, the oil tanker built in 1903, has a displacement-length coefficient, or coefficient of fatness, of 165, and the other ship, which has proven superior, has a coefficient of fatness of 197, in other words, is a fatter ship than the first vessel. I hope the author of this paper will present us with the curves of resistance, residuary and frictional, in the case of these two ships, also the trial trip data, so that we can see how it is possible to obtain this very remarkable economy which he has presented for our consideration. More data is necessary to make this example complete and comprehensible.

Example No. 2 refers to two ships which require the same total horse-power

to drive them at the given speed of 10 knots. If we go into the question of the skin effective horse-power and residuary effective horse-power, we find that in the case of the 370-foot ship, the residuary resistance is more than 38 per cent of the total resistance, while the percentage of residuary resistance in the case of the 400-foot ship is about 35 per cent. In a ship of this class, where we are interested in the maintenance of this speed of 10 knots at sea, the question arises as to whether this 370-foot ship with a larger residuary resistance in per cent of the total resistance than the 400-foot ship, will maintain her sea speed as easily as the 400-foot ship. I think the experience of everybody has been that in order to obtain a certain speed at sea, we have to build the ship for more speed in the smooth-water trials, and that as a general proposition if we take two 10-knot ships, one of which will drive at 10.5 or 11 knots in smooth water easier than the other will at this increased speed, we will find that it will be easier to maintain 10 knots with that ship in sea service than with the other ship whose power curve runs up more quickly above 10 knots and requires at 10.5 or 11 knots more power than the first ship. Has Mr. Rigg drawn his conclusions in Example No. 2 entirely from the results of model tank tests? It will be interesting for us to have the results of these tests, also to know the relative performances in service of these vessels.

Referring to Example No. 6, it will be interesting to know what actual economy is realized in sea service with a coastwise steamer with a bulbous form of bow.

The results cited in Example No. 7 seem to conform to the experience that, generally speaking, if we wish to design a ship for shallow water we must adopt such a form as will in deep water, at a higher speed than the designed speed in shallow water, have a comparatively moderate wave-making resistance.

In the last example, No. 8, it seems to me the reason for the gain is very apparent. We find there that the prismatic or longitudinal coefficient in the case of the boat in column A is 0.634, and in the case of the boat in column B is 0.568; in other words, the longitudinal or prismatic coefficient has been reduced by increasing the area of the midship section and fining the ends of the vessel.

From an inspection of the contours of residuary resistance given in Mr. Taylor's work, we find that we can expect to obtain, in the case of the two vessels cited in this last example, a reduction in residuary resistance by this reduction in the longitudinal coefficient of as much as from 40 to 50 per cent. We can consequently accept some increase in skin resistance and still materially gain by the changes made in dimensions and proportions of the vessel at the speed in proportion to the length at which it is designed to run.

Mr. George Simpson, *Visitor*:—This is a very interesting paper, but I think that Mr. Rigg is a little on the wrong track. I am of the opinion that all this talk about the prismatic coefficient is entirely wrong as applied to a freight carrier. It is all right when we are dealing with high-speed ships, as Mr. Taylor has shown and proved, because to put beam on with these vessels to fine the ship toward the ends is an entirely different matter.

When we deal with cargo carrying vessels, in which we must have a certain amount of midship area, we all make the boat as dead-flat as possible. We do not do this to save 3 per cent in horse-power, because every engineer knows that you can more than eliminate that amount, or augment it, by a slack indicator spring. Then why do we increase mid area? Mainly to get the boat as short as possible to carry the deadweight, because every one connected with ship design knows that length is the important factor in the ship, and the expensive one. Beam does not cost one-tenth of what length does.

As to the ships Mr. Rigg refers to, the examples he gives, I happen to know of as their designer. One of them he calls the Mars class. It is not the Mars class, it is the Everett class, the pioneer of the present colliers in this country and of which the Mars class is a copy. I fixed these proportions and can say something about them. In fixing these proportions I aimed to shorten the ship. If I were designing these ships to-day, I would shorten them still further. If it is of interest enough to put in this discussion—I have not the data with me—I will prepare a table showing the elements of the boats in a competitive design for a cargo vessel probably the most interesting that has been brought out in this country (see table following).

DIMENSIONS PROPOSED BY DIFFERENT BUILDERS FOR A GIVEN DEAD-WEIGHT, SPEED AND DRAUGHT.

	1.	2.	3.	4.	5.	6.
Length overall	368′	381′	376′	379′	370′	361′ 3″
Length between perpendiculars	355′	365′	360′	362′	355′	345′
Breadth mld	48′ 6″	48′ 6″	48′ 6″	48′ 6″	48′	48′ 3″
Depth mld	30′ 0″	31′ 6″	29′ 0″	31′ 9″	30′	30′ 0″
Load draught, maximum	23′ 6″	23′ 6″	23′ 6″	23′ 6″	23′ 6″	23′ 6″
Speed at sea (knots)	10.5	10.5	10.5	10.5	10.5	10.5*
Dead-weight	6,125	6,125	6,125	6,125	6,125	6,125†
Load displacement	9,140	8,575	9,050	8,600	9,100	8,800
Coefficient of displacement	.791	.746	.772	.73	.79	.787

*As built 11 knots. †As built 6,200 tons.

That design was contemporaneous with the Mars class Mr. Rigg refers to. A number of large shipbuilders went into this competition. The owners gave complete specifications as to what they desired in the ship, but left out everything in the way of dimensions. They said: "We want a vessel to carry so many hundred tons deadweight on a certain draught, the ship to go a stipulated speed." Everything else was blank. The beam was stated as so-and-so, and they gave their

reasons for that. The design that won out was 25 feet shorter than the longest one, and I can also tell Mr. Rigg that the firm with which he is connected were just about 10 feet longer than the successful one. That all comes back to this: That in a cargo boat the prismatic coefficient amounts to little or nothing, because we all of us would make the boat a box amidships if it were desirable. You have got to have so much dead-flat length and when you come to the ends what can you do? You probably have one-sixteenth of the length at each end that must be fined. A hundred designs could not vary much in the fining the ends within that limit, which brings us back to the engineering feature. If one boat does better than the other it is due, in all probability, to a better design of the propeller and the run of the vessel. In my opinion, to give examples of freight boats, and to bring in the prismatic coefficient is begging the question. It may be all right in the case of a battleship. Let me show you where it comes in in the case of a battleship. I do not think I am giving away any state secrets in mentioning the Rivadavia and Moreno. A certain firm took those boats. The speed-length ratio was increased at the last moment. They wanted more speed. Three feet on the beam of the boat enabled the prismatic coefficient to be reduced and the ends of the ship to be correspondingly fined, and if these boats are a speed success it is due to the change referred to, but of course this is dealing with a 22.5-knot vessel. On the other hand, if Mr. Taylor, to whom Mr. Rigg refers, had been asked how he could economize horse-power with usual proportions in a cargo steamer of .79 or .80 block coefficient, I am afraid he would admit that little if any appreciable saving could be made.

Mr. Thomas M. Cornbrooks, *Member:*—In connection with the example on page 231 regarding Mars class, I desire to make a correction in the statement made by Mr. Rigg. I note Mr. Rigg gives the credit for the performance of this vessel to the experimental model basin, while Mr. Simpson claims the credit for himself; neither statement is entirely correct. In the first place, the keel of this vessel was laid in October, 1908, the model was tried in the basin in March, 1909; consequently the trial had no influence on the lines.

Mr. Simpson states that the Mars class is a copy of the Everett. While the outboard appearance of these vessels are similar to the Everett, I cannot see how the appearance would affect the economy. The lines for these vessels were designed by the company with which I am connected and the credit for the performance belongs to them.

It is evident that Mr. Rigg is a great believer in the experimental model basin, and it is to be regretted that he did not secure more reliable data in regard to some of the examples which he presents.

On page 234 he speaks of a Sound steamer which has recently been designed and makes a very broad statement in reference to indicated horse-power and saving in coal bills. I would like to ask Mr. Rigg whether his conclusions are based on model experiment or on theory. The difference in indicated horse-power shown

is 500. Figuring from Mr. Taylor's curves the effective horse-power for each vessel works out as follows:—

	"A"	"B"
Frictional	831	837
Residuary	666	654
Total effective horse-power	1,497	1,491

at 50 per cent efficiency equals "A"—2,994, and "B"—2,982 indicated horse-power, or a difference of 12 indicated horse-power.

Constructor Taylor says, in regard to "The Influence of Midship-Section Shape upon the Resistance of Ships:"—

"The shape of the midship-section has a comparatively minor influence upon the speed, and that the midship-section coefficient may range from .85 to 1, with very little effect on speed, and may be made as low as .70 without a material increase in resistance.

"Also increased beam means increased disturbance of at least a portion of the water which a ship passes."

In view of the foregoing, it is difficult to see where Mr. Rigg secures a saving of 18 per cent in the coal bill.

Mr. Rigg:—Referring to Mr. Chace's request for more data concerning the examples given; taking them in order the following can be stated:

Example No. 1.—Curves of effective horse-power cannot be given, for the first ship they do not exist, and for the Mars, though the model was run, I am not in possession of the curves. The curves of indicated power are given in the text of the paper.

Example No. 2.—It is probable that the residuary resistance of the 370-foot ship would be too high for general ocean work. She was designed for short coastwise runs, comparatively close in shore, and the chances of being badly slowed up not as great as off shore. The example was suggested by an actual design coming up in the ordinary course of business and worked up from published tank test data, and not from actual tests for the two boats.

Example No. 6.—Additional data connected with this vessel has been incorporated in the body of the paper.

Example No. 8.—I am glad Mr. Chace agrees with me, because Mr. Cornbrooks decidedly does not. I will refer to this vessel later.

Referring to Mr. Simpson's remarks, on looking over my freighter examples, I am unable to find any reference to the prismatic coefficient; nevertheless, though the range of choice is limited in full models, the prismatic coefficient is still of importance. The object of Examples Nos. 2 and 3 is to show what can be done by judicious shortening of the ship, always watching for the point where the residuary resistance begins to increase too rapidly.

With reference to Example No. 1, I can only repeat that the ship therein referred to is the Mars class. I have no data on their forerunners, the Malden class.

Referring to Mr. Cornbrooks' contribution to the discussion, I am glad to be corrected as to dates in connection with the Mars design and the model trials. The wording of the paper evidently does not give Mr. Cornbrooks' firm the full credit that is their due.

With regard to Example No. 8, my conclusions are not based on tank tests for this particular vessel, but use was made of actual tank tests for a similar ship in deducing the figures given. I understand the vessel referred to in this example is being built, so trust Mr. Cornbrooks' figures are right even at the expense of making mine wrong. I am still of the opinion, however, that form "B" is materially the better one for driving. There is no question of rough water, other than that experienced in a broad river or estuary.

THE PRESIDENT:—I am quite sure you will agree with me that the thanks of the Society are due to Mr. Rigg for the interesting paper which he has presented and they are now extended to him.

The next paper is a very important one, and will probably provoke some discussion—the paper postponed from yesterday. Before calling on Mr. Peabody I will make an announcement, and trust that authors will bear the suggestion in mind.

It is the sense of the Council that hereafter authors of papers shall, in addition to the papers, furnish abstracts of same which shall be distributed and used at the presentation of the papers at the meetings.

Unfortunately, I must leave you now and I ask Admiral Capps to fill my place for the balance of the session. I shall be happy to see you all this evening, and now will say good afternoon. (Applause.)

(Vice-President Admiral W. L. Capps in the chair.)

THE CHAIRMAN:—It is always our privilege, at the conclusion of the term of office of a president, to let him know what we think of him. If our beloved president thought that by leaving us early this afternoon he was going to escape any such expression of opinion on our part, he is very much mistaken. I now call on Mr. McFarland to propose a resolution expressive of the feeling of the Society on this occasion. * * *

MR. WALTER M. MCFARLAND, *Vice-President:*—Mr. Chairman, Mr. President, fellow members of the Society, our Constitution provides that at the end of three years we must have a change in the incumbent of the office of president. I know that I voice the unanimous sentiment of the members of the Society when I say that if it had not been for that clause in our Constitution our president would have remained in office indefinitely, or as long as he was willing to serve, and we should still have the dear man who has served us so ably for the past three years.

As Admiral Capps has very well said, now that the term of office of the president is about to expire, we want to have him understand how greatly we feel our indebtedness to him for the able manner in which he has presided over our deliberations. I think you will all agree with me when I say that he has been a model presiding officer. He has conducted our affairs with decorum, with the best of taste, and in some unfortunate cases where there has been a tendency for hard feelings to come about, he has shown the utmost tact in smoothing things over. In one case that some of us know of particularly, by his rare tact he avoided a very serious complication. In other words, he has been all that a presiding officer could possibly be. His work in the interests of the Society from the very start has been of the very highest character. He has been one of our cornerstones, one of our pillars, and I do not know what I might say, if I had a sufficient command of language and metaphor, to show all that he has done for the advancement of the Society.

But above all—and I know I voice the sentiment of those who have the honor of counting themselves as his personal friends, and I am sure you will all echo what I am about to say: I repeat that above his ability as a presiding officer, and above his ability as a marine engineer, he is at the head of the profession—come his magnificent character and his splendid, lovable qualities as a man. Every one of us who has had the privilege of his friendship for many years has grown to love him more and more as the years have gone by, and I can say for myself that I know of no higher type of American manhood than Stevenson Taylor, President of our Society. (Prolonged applause and cheering.)

I now ask you to join me in the formal presentation, as I voice your unanimous sentiment, of a resolution for a vote of thanks to President Stevenson Taylor, for the admirable way in which he has conducted the affairs of the Society of Naval Architects and Marine Engineers during his term of office, and that we wish him long life and prosperity. (Applause.)

Chief Constructor R. M. Watt, *Vice-President:*—I take great pleasure in seconding the motion. It was my privilege to be a delegate of this Society as well as a representative of the Navy Department at the International Jubilee Congress held in London in the summer of 1911. Nothing could possibly have raised this Society to a higher level in the opinion of our British and Continental colleagues than the dignified, able and intelligent manner in which our beloved president represented us. It is, therefore, my special privilege to second this motion of thanks.

Engineer-in-Chief Hutchison I. Cone, *Vice-President:*—Mr. Chairman and gentlemen of the Society, while it is not my habit to indulge in public speaking, yet I feel so strongly, personally as well as a member of this Society, on this occasion, that I feel that I must support Mr. McFarland's motion. I also had the honor of representing this Society abroad under the leadership of our president at the Jubilee Meeting, and since that time it has been my pleasure, which I have

appreciated very much, to correspond at times with our president on matters concerning the Society, and I know from my own knowledge that the esteem and personal effection with which Mr. Taylor is held by high officials in Washington has contributed in no end of ways to the advancement of this Society. I further wish to say that I consider the stamp of his personal example on the members of this Society as one of the greatest assets of the Society. I think you will all agree with me that this meeting has been very successful from the point of view of interesting papers presented and the number of members in attendance at the meeting, but to me, throughout the whole meeting, there has been one great drawback, and that is the fact that it is the last time that we will hold one of these annual meetings under the able leadership of Mr. Stevenson Taylor. (Applause.)

Commodore Jacob W. Miller, *Vice-President:*—May I add a few words to what has been said regarding our worthy president.

It has been my good fortune to be associated with him for over twenty-five years; during that period many contracts between the company which I represented and his corporation were made. Now we all know the close relationship between the owners of steamships and the builders thereof, and how difficult it is always to avoid friction in settling business matters of large import. It is, therefore, a great pleasure to state that during our long official and personal acquaintance there never arose between us any questions which were not readily and speedily adjusted; such a result is only possible when a contractor acts from the highest motives. So thoroughly did our corporation appreciate the man with whom it had dealings, that one of the latest contracts given him consisted of only two or three pages, although the amount involved was nearly $2,000,000. The result of our confidence was not misplaced, the witness thereof being the steamer Commonwealth—perfect in its design and appointments and equipped with even more completeness than the specifications required. The integrity of the man has always been supplemented as shown since his occupancy of the presidential chair by a courtesy which is rare, and therefore I personally wish to add my own eulogy of one with whom I have been associated for so long a period, and whose personal regard I consider one of the greatest assets of my life.

The Chairman:—Gentlemen, it is needless for me to attempt to add to what has been so happily said by Mr. McFarland, Admiral Watt, Admiral Cone and Commodore Miller. Most evidently, what they said came straight from their hearts. Had I not been sure of the character of our tribute, I might have hesitated to ask our president to sit down and remain a few minutes; but he now knows what we think of him and has had from the lips of his colleagues expressions of esteem and affectionate regard that must bring to him, as to us, a tightening of the heart strings. To have such a unanimous expression of deeply appreciative feeling from a body of men of this kind, which has had to be ruled, at times, with an iron hand by its presiding officer, is truly a tribute of which any man should be proud, and, I need hardly add, is thoroughly deserved by the recipient.

Although we are expressing our great regret at the relinquishment by Mr. Taylor of the duties of president, we can console ourselves with the thought that our past good fortune in the choice of the incumbent of this high office is being continued. The standard heretofore established by your presiding officers has been notably high, and the Society, while deeply regretting the departure of its retiring president, is to be congratulated on having elected as his successor one who will continue the example of his predecessors and add to the splendid traditions of the presidency of this Society.

I now ask you to give a rising and audibly expressive vote of appreciation to our retiring president. (Members rose and there was prolonged applause and cheering.) * * *

President Taylor:—Admiral Capps has well said that such a testimonial as this brings a choke to the throat. I hardly know which to do most, grieve or rejoice. Let me say to you now that three years ago when you elected me president I looked upon that election as the climax of such career as I may have made. It seemed to me then, and it seems more so now than then, to be the highest point of achievement that I could possibly reach. When one reaches the top of the hill of achievement one is apt to grieve, and that is why I say I hardly know now whether to grieve or rejoice, but I am sure you will believe me that after all I rejoice very much more than I grieve.

I do not know what I can say to those who have spoken and to you gentlemen. That I have done anything to warrant such tributes has been to me an unthought of matter. I could not possibly have expected them, and I thank you, one and all—I thank you from the bottom of my heart. (Applause.)

The Chairman:—The next paper will be the one held over from yesterday, entitled "Developments in Oil Burning," by Mr. E. H. Peabody, Member of the Society.

Mr. E. H. Peabody, *Member:*—Gentlemen, I feel that my paper comes at an opportune time. The little incident of good fellowship that has just taken place perhaps will prepare the way for me.

DEVELOPMENTS IN OIL BURNING.

By E. H. Peabody, Esq., Member.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

The advocates of peace who urge the disarmament of nations overlook one great service which the navy renders, besides giving us the security of potential power of defence, namely, the incentive to national progress brought about by the necessity for continuous advance in engineering development forced upon the government in competition with other powers.

The introduction of high steam pressures, superheat, water-tube boilers, turbines and the reduction gear are examples in point, and, perhaps as conspicuous as any, the development of the art of burning fuel oil to meet new requirements.

It may be urged that the money spent for the building and maintenance of the Navy, if devoted to commercial pursuits, might result in greater progress, but there would be lacking almost wholly that powerful prime mover—necessity, and necessity does continue to give birth to invention, notwithstanding the claim of inventors who find the relationship the other way round.

The "mechanical atomizer," so-called, is understood to mean a device which sprays or atomizes oil or other liquids by means imparted to it by pressure alone, without the use of compressed air or steam or other exterior atomizing agent. Owing to its simplicity and to the fact that no fresh water is wasted, it is being extensively used in the merchant marine, and it has possibilities which, I believe, will ultimately bring about its adoption on shore.

But in the adoption of the mechanical atomizer, we are merely following the lead of the Navy, for it may be safely said that, without the stimulus given to the device, and the new interest aroused in it by the activities of the navies of England and the United States, there is little doubt that older methods would still be almost exclusively in vogue.

That this change has been and will be slow is not to be wondered at, awaiting as it must, perforce, the growth of the oil-producing industry, but with the increased supply of oil its use as a fuel has spread, and with the increased use of oil has arisen the need of better methods of handling;

and, following the necessity, the better methods have been developed, first in naval practice, and now in wider fields.

By better methods I do not mean merely the substitution, for steam and compressed air as atomizing agents, of the relatively high oil pressure and centrifugal force utilized in the mechanical burner—there is nothing very new about that—but furnace arrangement, air distribution and control, and improvements in the process have all been necessary to meet the severe requirements of modern practice and to realize the conditions which make for success.

I have not had occasion to hunt up the history of the art to the extent of determining who was the actual pioneer in the use of the mechanical atomizer, but it is certain that over twenty years ago oil was atomized by mechanical means, along very much the same lines as those employed to-day.

Messrs. L. Schutte & Co., of Philadelphia, in 1888 issued a catalogue describing their "cyclone burner." This burner, as its name implies, was constructed with a mechanism for delivering a spiral air blast around the oil tip, but the tip itself and the description of it bear all the earmarks of a perfectly good mechanical atomizer—and it should be remembered that this was in the early days, twenty-four years ago. With all due respect, however, to early inventors, the importance of whose work I do not underestimate, the situation is very well summed up by an eminent engineer who, writing recently from England, says of mechanical oil-burning systems:—"The priority of invention is very doubtful, but there is not the slightest doubt that the credit for the actual application, in practice, is due to the British Admiralty, as, when they first took the field, not one of the systems up till that time in use (about eight or nine years ago) had shown itself capable of developing the full power from a boiler as demanded by the naval requirements and as obtainable with coal, and it was the Admiralty who first showed that it was possible to force a boiler to the high degree required for naval work, with oil firing, at the same time obtaining a high efficiency and no smoke. After they had once indicated the practicability of this, naturally the others all followed suit, and although they have claimed against the Admiralty priority of patents, not one of them has succeeded in maintaining this claim, and therefore, on this side, the credit for the actual application and development of the system, I think, must be given to the Admiralty."

We must, in this country, gracefully accord to our English cousins the credit for this first modern development of the mechanical oil burner, for it was not until 1907 that our navy started the reform by calling for the system to be used in conjunction with coal in ordinary furnaces.

It is true that the United States Naval "Liquid Fuel Board" appointed

by the late Rear Admiral Melville, the senior member of which was Commander, now Rear Admiral, John R. Edwards, devoted a chapter to "Mechanical Burners" in their justly celebrated report published in 1904—probably one of the most widely read and frequently quoted treatises on the subject of oil burning in the world. It is clear that the Board appreciated the advantages of the mechanical atomizer, but their actual trial of the device was confined to a few experiments with a design which did not show great promise, and the bulk of their work was carried out with steam and air atomizers. The reason for this is plain. At that time in this country oil had been burned in considerable quantity for limited periods as the various oil-bearing territories had been developed. A great variety of oil-burning "systems" had come into existence, many of them of considerable merit, but depending on compressed air or steam for atomizing the oil. On the discovery of the big Texas "gushers" in 1901, flooding the market with oil available for fuel purposes, these various systems, which heretofore had been used on land only, were at once adapted for marine use, and many new inventions, too, were added to their number. When, soon after, the Navy began to investigate oil fuel all these manufacturers and inventors demanded a hearing, and it was a distinct achievement to have sorted out and tabulated this legion of oil burners. The Board had more than enough to do without going abroad, where necessity had indeed already demanded the mechanical type, but where no such assurance of its success existed as is the case to-day.

In 1907 the mechanical oil burner had attracted little attention in America. But English experiments were being brought to successful issues, and far-sighted officers of our navy (they are members of this Society) demanded that the improvement be introduced into our service.

With the continued increase in oil production the use of this ideal fuel is rapidly extending, particularly for marine purposes, and it seems worth while therefore to point out some of the main characteristics of the mechanical atomizer and modern methods of handling it. In attempting this the writer will of necessity have to look at the subject from his own point of view, and in the light of his own experience and the experiments carried out by The Babcock & Wilcox Company.

ATOMIZATION VS. GASIFICATION.

To begin with, Commodore Isherwood's conclusions of some forty years ago hold good to-day; namely, that atomization of the oil, as distinguished from vaporization or gasification in the burner, "is the only method that has been attended with success." There are not wanting those who still claim

advantage for those forms of apparatus which, by various methods of treatment of the oil, admit the fuel to the furnace in the form of vapor. These systems, while successful in metallurgical work, have no standing in boiler practice for the reason that not only do they show no gain in efficiency but, on the contrary, they result in very poor capacity, the latter feature alone making them undesirable for marine use. At the same time some of these devices are ingenious and interesting and I have taken as an illustration of the vaporizing type of burner an apparatus patented in England in 1907 by Mr. L. Dürr (Fig. 1). There are two burners in the form of retorts, a big one and a little one, the idea being that the little burner by playing a flame on the outside of the big burner will gasify the oil for the big burner and for itself as well. Several patents followed this one, each correcting some shortcoming of the preceding.

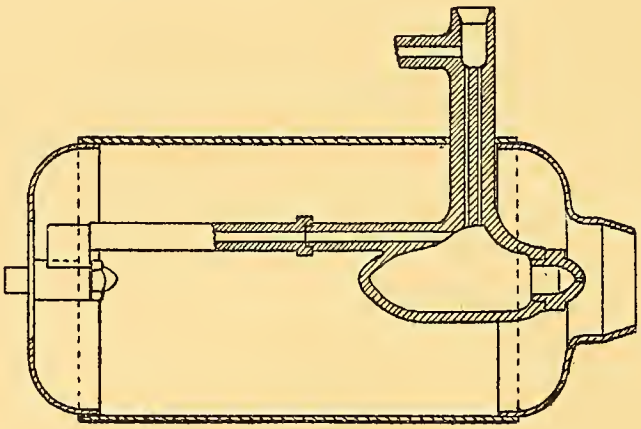


Fig. 1.—Dürr Burner.

The well known Koerting process patent, taken out in this country in 1905, contains a claim which covers: heating the liquid oil unmixed with air or other gases to a point above its normal boiling-point, maintaining the oil in a liquid state by pressure and delivering the superheated oil into a combustion chamber supplied with air, whereby the rapid disintegration and vaporization of oil in the presence of air are secured.

The idea here, as is more fully pointed out in the patent specifications, is that the heat stored in the oil at high pressure will cause the liquid to flash into vapor when released at low pressure, exactly as water, heated above 212° F. under pressure, would flash into steam if released to the atmosphere. This is an exceedingly ingenious way of converting at least part of the oil into vapor without atomizing it, but as a matter of fact no gain results from this partial gasifying of the oil. This question has been

tested out experimentally and what is more to the point, nobody is doing it, not even the users of the Koerting apparatus itself. The dangerous expedient, therefore, of heating oil above its flash-point at atmospheric pressure is not found necessary.

EFFECT OF HEATING OIL ON VISCOSITY.

The real value of heating the oil is rather a mechanical one—namely, to reduce the viscosity of the liquid so that it can be forced through the small passages of the burner and given a rapid whirling effect, sufficient in the more limpid condition of the oil to reduce it to a fine spray through the action of centrifugal force when liberated from the tip.

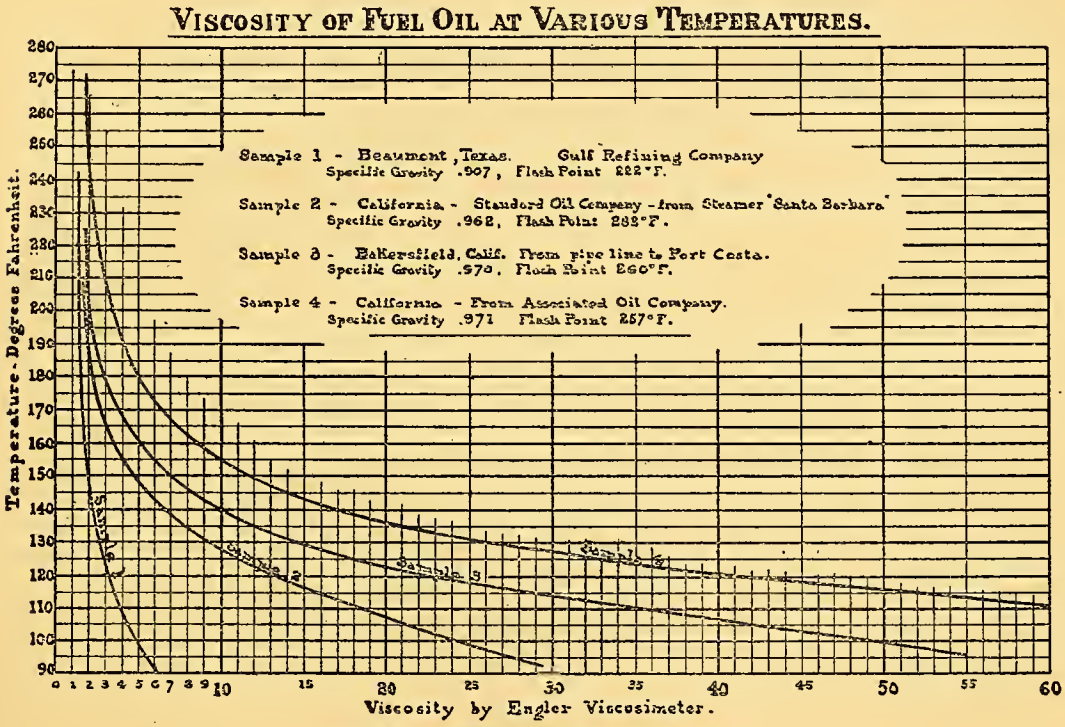


FIG. 2.—TEMPERATURE-VISCOSITY CHART.

It will be found from a study of fuel oils that, while the viscosity is tremendously affected by changes in temperature at the lower ranges, very little difference in viscosity results with heating or cooling as the temperatures approach the flash-point. A number of viscosity tests at various temperatures on a variety of oils were made for the writer by Mr. E. G. Bashore, chemist for The Babcock & Wilcox Company, the results of which are shown graphically in Fig. 2 and serve to illustrate this condition.

With all ordinary oils it may be considered that heating within 50° F. of the flash-point will be sufficient to render the oil suitable for use with the mechanical burner, and in the case of many of the lighter oils even this heating is unnecessary, the oil being sufficiently limpid at ordinary atmospheric temperatures.

MECHANICAL SPRAYING.

Several methods of spraying oil by mechanical means have been suggested, such as forcing the liquid through a very fine aperture, forcing a jet of oil at high velocity against some object or against another oil jet, throwing the oil off from a rapidly revolving table or disc, or giving the liquid itself a whirling motion and reducing it to spray by centrifugal force.

In 1902 the writer tried the first idea and succeeded in making a very poor flat-flame mechanical atomizer by forcing the oil between two flat surfaces pressed closely together, and in 1907, when in answer to the Navy's call we took up the matter of mechanical atomizing seriously, we tried some of the other schemes. The experiment of making two round jets of oil strike each other, on the principle of the acetylene burner, resulted very interestingly in a flat spray—not fine enough, however, with heavy oils to be practicable. A mechanical atomizer, or, as it was called, a "self-atomizer," consisting of eight small jets meeting at a central point, was patented in England in 1904 by Mr. Charles Ferdinand de Kierskowski Steuart. It is a good example of spraying by forcing jets of oil to strike each other, but otherwise has attained no importance in the art.

The only method of atomizing fuel oil mechanically which has attained any practical success is that wherein the oil is given a whirling motion inside the burner tip. There are two distinct means for doing this, first, by forcing the oil through a passage of helical form, like a screw thread, and second, by delivering the oil tangentially to a circular chamber from which there is a central outlet.

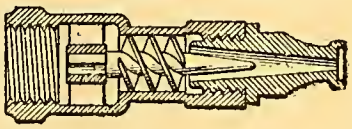


Fig. 3.—Schütte Sprayer.

As an illustration of the first form I have selected the "spraying nozzle" patented in the United States in 1895 by Mr. L. Schütte. This is shown in Fig. 3. Judging by the patent, the inventor had principally in mind, with regard to this particular apparatus, the spraying of water, but the device is

an excellent example of the use of the helical passage for giving the liquid a whirling motion.

Another adaptation of the same idea is shown in a patent taken out in England in 1899 by Mr. James Howden (Fig. 4).

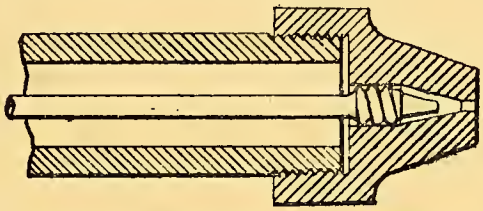


Fig. 4.—Nozzle of Howden Burner.

He refers to heating the oil by means of live or exhaust steam or the waste gases, pumping it into an accumulator or air receiver for neutralizing the pulsations of the pump, and then projecting the oil into the furnace in the form of fine jets or spray by passing it through a nozzle which he describes as having helical grooves on a part of the spindle within the nozzle, so as to impart a whirling motion to the oil. Howden's burner is adjustable in that the taper spindle moves "up and down" in the taper passage leading to the nozzle orifice. This movement of the spindle increases or decreases the area of the outlet passage, thus controlling the amount of oil delivered by the burner, but the helical passage is not affected. The single claim of the patent covers the combination of the adjustable nozzle "encircled by an adjustable annular opening through which the air for combustion, supplied by a fan or blower and heated by the waste gases from the boiler, issues and mixes with the oil jets as they enter the furnace."

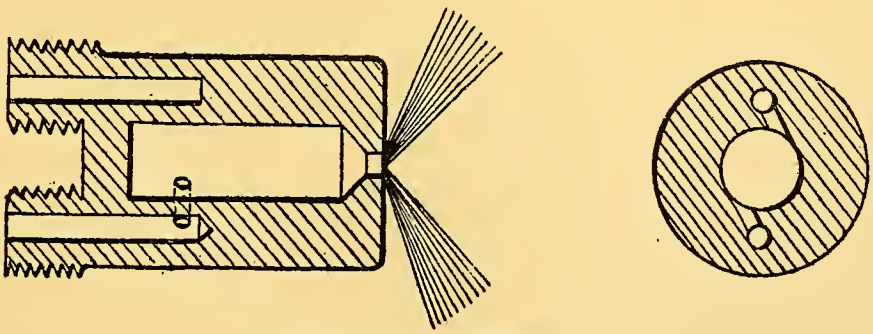


Fig. 5.—Jones Burner.

Howden does not claim the atomizer, and its similarity to the Schütte-Koerting burner shown in Fig. 35 is suggestive. The Schütte-Koerting burner, however, is not adjustable.

The idea of delivering the oil tangentially to a chamber inside the nozzle is shown in a burner patented in England by Mr. Albert Edward Jones, in 1907 (Fig. 5). This invention as a matter of fact contemplates the use of a gas or vapor in combination with a combustible liquid, and is not strictly what we consider a mechanical atomizer, but the device is almost a diagrammatic illustration of the tangential principle and for that reason I have reproduced it here. It may be considered that oil is forced into both tangential passages, or that only one is used, thus depending only on the whirling motion of the oil to cause the spraying.

A so-called "nebulizer of the heavier hydrocarbons," patented in this country in 1908 by Stringham and Elmendorf, is a good illustration of the further development of the tangential principle and is shown in Fig. 6. This apparatus was water-cooled, a precaution not found necessary in connection with boiler furnaces.

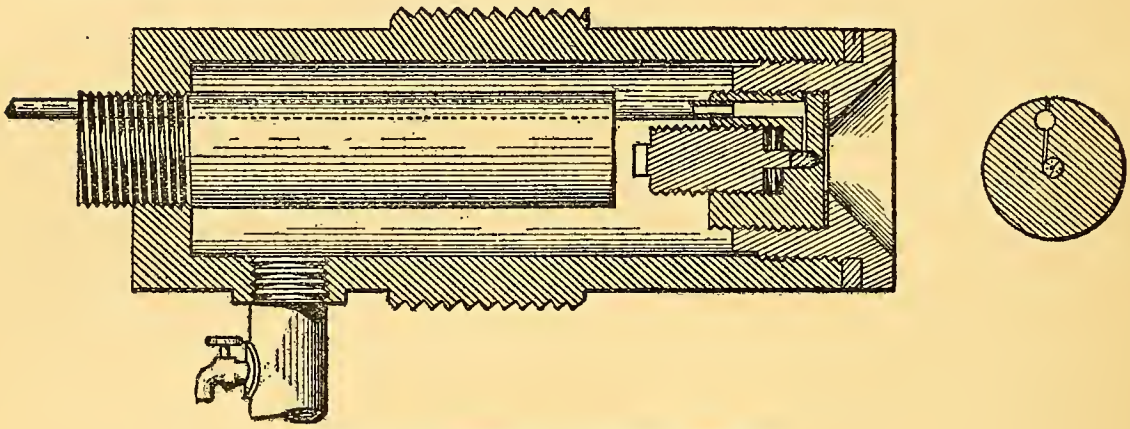


Fig. 6.—Stringham-Elmendorf Nebulizer.

Modifications or combinations of the tangential and helical forms of burners are frequently encountered in the art, and an illustration of one of these is shown in Fig. 7. This is an ingenious burner patented in England by Sir John Thornycroft in 1906, in which it will be noted that the oil passages within the tip are made variable in area of cross-section by an adjustment of the spindle, thus varying the quantity of oil delivered without alteration of either oil pressure or size of outlet passage. This renders the burner adjustable like the Howden, though by a different process, in that in the Howden burner the helical passages remain unaltered and only the outlet orifice is changed.

CONTROL OF CAPACITY.

This matter of adjustability of an oil burner, that is, the ability to change the quantity of oil delivered in a given time without changing the oil pressure or the velocity of the liquid through the tip, while attractive in idea and perhaps well sustained in theory, has no particular value in practice. It is a fact that the simpler forms of burners which do not possess this feature are quite, if not more, successful in regular operation on shipboard. The manipulation of the oil pressure acting on all burners at once presents in itself a simple means for the control of output through a wide range; a good burner will atomize moderately heavy oil with an oil pressure as low as thirty pounds, and from that up to two hundred or above. If this range is insufficient to

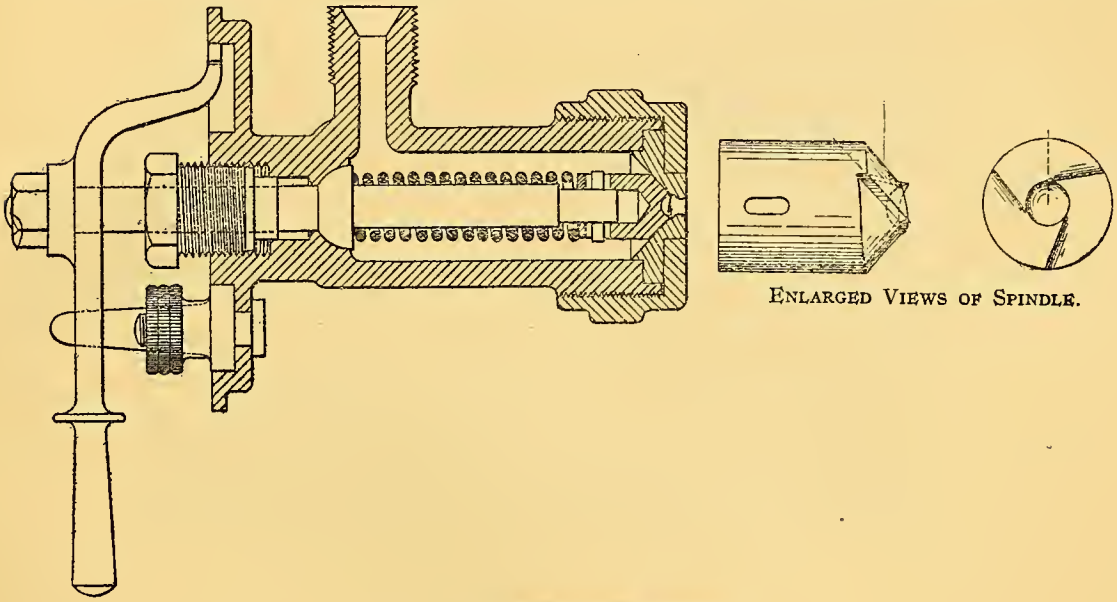


Fig. 7.—Thornycroft Burner.

meet the variable steam requirements, then it is easier and better to shut down a portion of the burners entirely than to attempt to adjust each individual burner separately, particularly as it is important to regulate the quantity of air for combustion admitted to the furnace at the same time the quantity of oil is varied. This air supply can easily be controlled for all burners by regulating the draft pressure, and the air can be closed off entirely when a burner is shut down. This puts the question of proper air supply more into the hands of the designer, requiring the operator to determine only the proper conditions of draft pressure for the plant as a whole, at the required capacity.

EFFECT ON CAPACITY OF HEATING OIL.

Another means of varying the quantity of oil delivered by all burners in addition to alteration of oil-pressure is available in alteration of oil temperature. Generally speaking, under working conditions any increase in temperature of the oil results in decreased capacity of the burners, the pressure remaining the same. The reverse is the case at low temperatures, the critical point depending on the relationship between viscosity and specific volume of the oil in question. This law is shown graphically in the diagram in Fig. 8

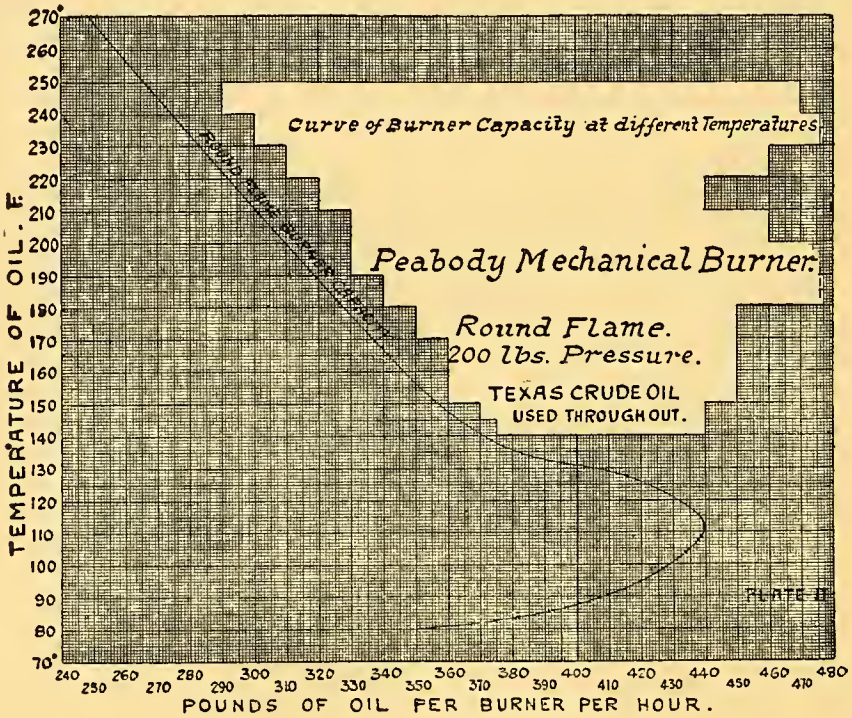


Fig. 8.—Temperature-Capacity Chart.

giving the results of a test on a sample of Texas oil of 18 "gravity" (degrees Baumé) and a flash-point of 240° F. The oil pressure was maintained constant throughout the test at 200 pounds and the temperature was raised by stages from 80° F. to the flash-point. The burner capacity increased rapidly up to a temperature of 110° where it reached a maximum. With continued heating it began to fall off and continued to do so throughout the range of the experiment.

REQUIREMENTS OF MECHANICAL BURNER.

It will be obvious, if oil is to be atomized by centrifugal force, that the best spray will be obtained by giving the oil the maximum whirling motion and reducing to a minimum the friction in the burner so that the whirling motion once obtained shall not be diminished before the oil is liberated. These are axiomatic principles, recognized by all, and no doubt each inventor believes he has best met the requirements.

It seems to me that the tests are these—that these are the controlling factors in the "survival of the fittest:"—

1. How heavy an oil will a burner thoroughly atomize?
2. What pressure and temperature are necessary?
3. What degree of simplicity has been attained in the design?

USE OF HEAVY OIL.

I might say here that any apparatus which will not handle heavy oil will have a very limited usefulness. Already the market is beginning to be supplied with very heavy oils from Mexico, there is considerable crude oil in California below 15° gravity, and the tendency will be more and more to use the heavier residiums. I believe that in a few years we will be using oils of 12° to 15° Baume as commonly as we are consuming oil of 27 and 30 degrees gravity to-day.

The Babcock & Wilcox Company recently received from the Texas Company, for experimental purposes, some Mexican crude oil having the following characteristics:—

Specific gravity at 60° F.	.981
Degrees Baumé at 60° F.	12.6
Moisture and silt, per cent.	3.5
Flash-point, degrees F.	310
Burning point, degrees F.	347
B. T. U. per pound (oil as received)	17,551

In appearance this oil was black and at temperatures of about 80° very sticky and viscous. On heating to 212° it turned to foam owing to the presence of so much water, and this failed to separate out, a sample of the oil being thinned down with ether to determine the percentage. Ordinary settling tanks would have been practically useless as the oil was so near the specific gravity of water. This oil was, however, successfully sprayed and

burned under natural draft, on being heated to 270° at a pressure of 165 pounds. A slight amount of smoke was formed which disappeared on a slight increase in the furnace draft above twelve-hundredths inches of water. The most noteworthy feature of the experiment was that the capacity fell off about 40 per cent from that obtained with the same apparatus with oil of 18 gravity.

This sample of oil was the worst the writer has ever seen, but they say there is more of it and it is a specimen of what we may have to handle in the near future.

DENSITY OF OIL.

Degrees Baumé.	Specific gravity.	Pounds per gallon.	Degrees Baumé.	Specific gravity.	Pounds per gallon.
12	.986	8.22	24	.913	7.61
14	.973	8.11	26	.901	7.51
16	.960	8.00	28	.890	7.42
18	.948	7.90	30	.880	7.33
20	.936	7.80	32	.869	7.24
22	.924	7.70			

The above table of densities is given for convenient reference.

PEABODY MECHANICAL ATOMIZER.

In the light of our experiments begun in 1907 we have come to believe that the best rotative effect on the oil is produced by the tangential delivery method, and it seems plain that the best way to reduce friction is to reduce the amount of surface to which the oil is exposed in its travel through the burner after it begins to whirl and until its exit from the tip. We have also come to attach great importance to simplicity in everything connected with oil burning and believe that the oil burner itself should be of simple construction, easily taken apart, and so designed that when taken apart all the small passages and wearing surfaces will be exposed for inspection, cleaning and repair.

The results of the writer's efforts to construct a burner to meet these requirements are shown in Fig. 9, Plate 1. Oil is delivered under pressure to an annular channel cut into the face of a nozzle upon which is screwed a tip having a very small central chamber communicating with a discharge orifice. Between the nozzle and the tip a thin washer or disc is inserted and held

firmly in place. This has a hole in the center corresponding with the diameter of the central chamber of the tip, and small slots or ducts, extending tangentially from the edges of the central opening outward toward the periphery of the washer, long enough to overlap the annular channel of the nozzle and put it in communication with the central chamber. The effect is that when the burner is assembled with the washer in place, oil is delivered through the ducts tangentially to the central chamber where it rapidly revolves and almost immediately is discharged through the orifice in the tip.

CHARACTER OF MECHANICAL SPRAY AND EFFECT ON COMBUSTION.

In order to correct a popular fallacy I beg to call attention here to the fact that no mechanical atomizer produces a revolving spray, but the particles of oil fly off in straight lines under the influence of centrifugal force, thus forming a hollow, conical spray. The fineness of this spray, *i. e.*, the minuteness of the particles forming it, has a most important bearing on the results obtained in the furnace. It is possible with some forms of steam atomizers to atomize oil so finely that no flame at all will be produced, the incandescent combustion chamber being filled merely with a clear, invisible gas and every brick being discernible. I doubt if this condition of flameless combustion can be produced with mechanical atomizers and heavy oil, nor is it desirable under any circumstances for the simple reason that it costs too much.

With the production of flame, however, furnace design assumes an added importance, for the flame must be distributed evenly and without localizing on the heating surfaces of the boiler, and the gases must be given time and space in which to expand and burn as nearly as possible to completion before being cooled and the flame extinguished by contact with the tubes of the boiler. These points become exceedingly vital when the boiler is forced to the requirements now demanded in naval service.

FURNACE DESIGN.

Having an atomizer, therefore, that will produce a fine spray with heavy oil and which is simple, reliable and easily handled, the problem becomes one, not of oil burner, but of furnace design and air distribution. Our work has been carried on, until recently, entirely with the Babcock and Wilcox marine boiler, a design having a furnace ideally suited for any volatile fuel and particularly for oil. A longitudinal section through this boiler fitted with mechanical atomizers is shown in Fig. 10. It will be seen that the characteristics of this furnace are: Large volume in proportion to the heating surface of the boiler; upward slope of the roof toward the rear, resulting in

increase in height and volume in the direction of the entering oil spray and thus providing room for the expansion and diffusion of the gases; small amount of boiler heating surface exposed, and, on the contrary, large exposed surface of incandescent refractory material, thus tending to maintain high furnace temperature and promote complete and rapid combustion of the oil; tubes almost parallel with path of the oil spray injected into the furnace from

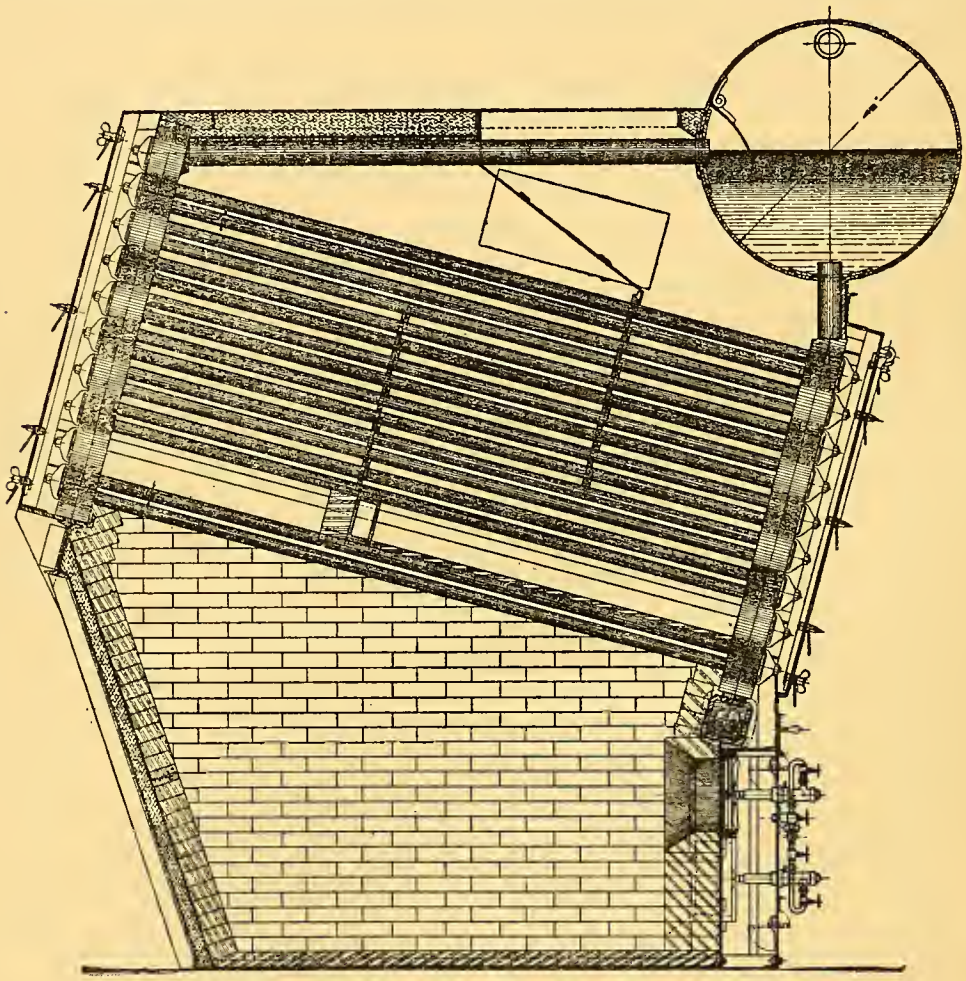


FIG. 10.—FURNACE OF BABCOCK & WILCOX BOILER.

the front, thus promoting proper distribution of the gases along the tubes and preventing local overheating; outlet from the furnace at the point most remote from the location of the atomizers, thus insuring long travel of the gases; and, finally, means for bringing the heated products of combustion into the closest possible contact with the entire amount of heating surface of the

boiler, discharging the waste gases into the uptake at temperatures but little above that of the steam generated. These conditions combined to relieve us of any worry about furnace design, or, to put it another way, we had been through all that before with steam atomizers.

Our experiments therefore developed principally into a search for the best method for admitting the air for combustion.

IDALIA EXPERIMENTS.

Having completed preliminary experiments with the atomizers in connection with a fire-brick oven built for the purpose and entirely separate from a boiler, the apparatus was removed to The Babcock & Wilcox Company's dock at Bayonne, N. J., where the steam yacht Idalia was moored preparatory to being laid up for the season. This vessel is fitted with a Babcock & Wilcox marine boiler containing 2,560 square feet of heating surface and 340 square feet of superheating surface. A simple and effective system of induced draft fans is installed capable of giving a suction in the uptake of 1 to $1\frac{1}{4}$ inches of water, and in addition to this a forced draft fan was set up on the dock and connected by means of a flexible duct to a sheet steel casing enclosing the oil burners on the front of the boiler. The tanks and scales for weighing the oil and water, and the oil pump and heater were set up on the dock and connected with the vessel by means of flexible pipes, the regular feed pump of the plant being used taking weighed water from the filter box. The engine and other auxiliaries were not in use, the steam being discharged to the atmosphere through a muffler so arranged, however, as to maintain regular working pressures on the boiler. All precautions were taken to prevent leaks and secure accurate data.

The object of these tests was to burn oil with mechanical atomizers, to burn as much oil as possible without smoke, and to secure the best possible evaporation per pound of oil.

Fifteen evaporative tests were made under a variety of conditions, the results given in Table I being selected as representative of the progress made. In between these tests considerable experimenting was done with various air-distributing arrangements, flat-flame burners, etc. The best performance was an evaporation of 7.47 pounds of water per square foot of heating surface per hour from and at 212° at an efficiency of 82.8 per cent at a rate of combustion of 6.17 pounds of oil per cubic foot of furnace volume per hour, with a draft in the uptake of .84 inch of water. The air in this test was admitted to the furnace through what we call an impeller plate (Fig. 11, Plate 97). Beginning with the cast iron cone with air slots on the side as

shown in Fig. 17, various other air distributors were tried, but none of these seemed to promise as well as the impeller, either as to smokelessness, gas analysis, ignition of the oil, or noise.

WYOMING TESTS.

Coal.—The contracts for the United States battleships Wyoming and Arkansas called for a series of four 24-hour guarantee tests with coal, the first to be at a rate of combustion of 15 pounds, the second at 25 pounds, the third at 35 pounds, and the last at 40 pounds of coal per square foot of grate surface per hour. The idea was to duplicate a possible severe war condition, and it was required that the evaporation per pound of combustible in the final test should not be less than 11 pounds of water from and at 212°. This requirement was increased to 11½ pounds for the next contract after obtaining the excellent results in the tests on the Wyoming boiler.

As both the U. S. S. Wyoming and the U. S .S. Arkansas were fitted with Babcock & Wilcox boilers, and as both these ships were to burn oil in combination with coal, it was decided to build a special test boiler of exactly the same design and proportions, except that it was not as wide, set this up at the works, with an air-tight house around it, force air into this house under pressure to duplicate the conditions of a closed fire-room on board ship, and after making the guarantee tests with coal continue the experiments with oil, and with oil and coal in combination. This plan proving acceptable to the Engineer in Chief of the Navy, the boiler was built and tested under guarantee conditions by a board of naval officers, of which Capt. C. W. Dyson was the senior member.

As this same boiler was later tested with oil fuel, the comparison with coal is of general interest, and I have therefore copied the results of the coal tests from the board's reports (Table II). It will be noticed that a fifth test was made at the high rate of combustion of practically 70 pounds of coal per square foot of grate per hour. This was not part of the guarantee but was made at the request of the builders to show the possibilities of forcing the boiler. In this test, 14.76 pounds of water were evaporated from and at 212° per hour per square foot of heating surface.

Preliminary Tests with Oil Fuel.—After the completion of the coal tests the boiler was thoroughly cleaned of soot and ashes, fire-bricks were laid on the grate bars, and the front was arranged to receive the oil burners and air-distributing device.

While the results of the Idalia experiments had been promising it was desired to materially increase the capacity, .45 pound of oil per square foot of heating surface and about 6.2 pounds per cubic foot of furnace volume

having been the maximum in those tests. In this we were assisted by the fact of having available a strong closed fire-room draft and a powerful steam jet in the stack. Much experimenting was, however, found necessary, almost entirely in the direction of air admission and distribution, some two months being devoted to preliminary trials of various forms of apparatus.

Again the flat bladed impeller plate was found to be most suitable, a number of different designs of this being tried out, among which may be mentioned one having adjustable blades.

Finally, with the grate bars in place, six burners and impellers were installed, two in each fire door, and a test was made resulting in a combustion of .72 pounds of oil per square foot of heating surface and 11.6 pounds per cubic foot of furnace volume, a very distinct advance over the Idalia performance.

The grate bars were then removed, the ash pan lined with fire-brick, a second row of burners installed below the first, and efforts to obtain still higher capacities were continued. The experiments indicated that a considerable number of smaller burners and impeller plates was preferable to a few of larger size, and the furnace front was remodeled and fitted with eleven cast-iron boxes 13 inches square, each carrying an impeller plate 8 inches in diameter and each arranged to receive a burner. With nine of these burners in operation an evaporization of 13.16 pounds of water per hour from and at 212° per square foot of heating surface was obtained, burning .85 pound of oil per square foot. Results of tests indicating the progress of this preliminary work are shown in Table III.

These figures seemed to warrant our requesting that a board of naval officers be appointed to witness and supervise further tests. There was no guarantee connected with the matter, but we were desirous of demonstrating to the Navy Department what could be done with our apparatus, and also particularly to have the results checked by competent and thoroughly disinterested observers who should secure sufficient authentic data to place the final figures absolutely above criticism. It seems unfortunate that this plan is not more frequently followed as *ex parte* tests are always open to doubt, especially when the results are unusual.

Official Tests with Oil Fuel.—The following extract is from the beginning of the Board's report:

"This test was conducted by a Board composed of Captain C. A. Carr, U. S. N., and Lieutenant-Commanders J. K. Robison and John Halligan, Jr., U. S. N.

"The Board assembled at the works of The Babcock & Wilcox Company, Bayonne, N. J., about 10 A. M., November 28, 1910. The Board examined

the test boiler and its connections for water and steam tightness, the arrangements for measuring water and oil and the apparatus for taking data. All of these were found satisfactory, and the tests were proceeded with at once. In all these tests oil was used as a fuel.

"Civilian assistants from the office of the Inspector of Machinery, Bayonne, N. J., were detailed for the purpose of taking data. Another set of observers was furnished by The Babcock & Wilcox Company who took data independently. The data taken by the two sets of observers were compared, so that any errors in reading were corrected at once."

The report concludes as follows:—

"The Board was particularly impressed with the excellent results obtained with this boiler under the maximum rate of combustion, Test No. 1, which gives a combustion of 13.69 pounds of oil per cubic foot of furnace volume. This is the equivalent of about 75.34 pounds of coal per square foot of grate area in the same boiler when burning coal. The boiler in this test steamed freely with a very slight increase in the wetness of steam, and the falling off of efficiency was small for a rate of combustion much above the maximum ordinarily used on boilers of the Navy under forced-draft conditions.

"After all the tests were completed the boiler was opened, cleaned and thoroughly inspected for deterioration. No tubes showed any signs of distortion, and all tubes and headers were free of blisters. All baffles were in good condition and properly placed."

It may be interesting to note that the wetness of steam referred to in the Board's report did not exceed as a maximum 81 hundredths of 1 per cent, as shown in the results of the tests which are given in Table IV.

Oil and Coal in Combination.—The writer does not believe that two such different fuels as coal and oil can be burned in the same furnace at the same time with results in efficiency equal to those which can be obtained with either fuel alone. The problem, always difficult, of securing complete combustion of the volatile hydro-carbon becomes more difficult, and one fuel inevitably interferes with the other.

The injection of an oil spray over a coal fire is, however, a most effective way of boosting up the capacity of the boiler and for this purpose the combination has a wide field.

As noted above, the United States battleships Wyoming and Arkansas were to burn coal and oil in combination. Consequently after completing the oil tests we turned our attention to the best method of getting the two fuels to work together. Obviously the most satisfactory location for the burners is between the fire doors. But owing to the fact that the ash pan,

grate bars, and bed of coal and clinker on the grates combine to take up considerable space, there is bound to be a somewhat limited head room in the furnace. For this purpose the flat spray burner is well adapted, but the flat spray mechanical atomizer, as so far developed, does not at satisfactory capacities give as fine a spray as the round or conical spray atomizer. It is, however, possible, as we have found by experiment, to alter the shape of the flame from the round flame burner by manipulating the air for combustion. Thus, if the air be admitted through a horizontal slot, the flame will be diminished in width and increased in height, and, vice versa, if the air be admitted through a vertical slot the flame will be spread out sideways and decreased in height. The latter effect is what is desired in the combination of coal and oil. Consequently, while still retaining the whirling motion of the air, which we have found effective, we modified the impeller plate to approach the vertical slot idea, and in this way we were able to broaden out the oil flame over the coal bed so as to burn .6 pounds of oil per square foot of heating surface per hour in combination with a rate of combustion of 25 pounds of coal per hour per square foot of grate surface. This device is shown in Fig. 12, Plate 96, and Fig. 13, Plate 98. The space between the fire doors is occupied by a casting designed to carry two impellers side by side, each of an oval form as indicated. This casting is air-cooled and is provided with slide ways so arranged as to permit of substantial cast-iron shutters being pushed up in front of the impeller plates when the burners are not in operation, thus effectually shielding the impellers and the burners themselves from the radiant heat of the furnace. The burners and impellers therefore remain constantly in place while burning coal, and it is only necessary to put pressure on the oil line, slide the shutters down out of the way, and turn on the oil when the latter is needed. Figure 14, Plate 99, shows the front of one of the boilers of the United States battleship Wyoming as installed in the vessel.

If it is desired to operate with oil fuel only, the coal fire is allowed to go out, leaving the grate bars covered with ash and clinker to protect them from the heat, and the oil burners are lighted exactly as if no coal was used at all.

Natural Draft.—In the experiments described above forced draft had been available, and there is no doubt that the high velocity of the air thus secured is a material assistance in securing the proper mixture with the oil spray. It is often desirable, however, to run under natural draft conditions, particularly when the vessel is in port. For this reason a supplementary series of experiments was inaugurated for the purpose of adapting the apparatus to the requirements of lower draft pressures.

The principal changes found necessary were a modification of the shape of the blading and an increase in size of the impeller plates.

The results of the tests are given in Table V.

Table I.—Idalia Tests.

Babcock & Wilcox boiler with superheater; H. S. 2,560; S. H. S. 340; Peabody mechanical atomizers; Texas oil—lighter constituents removed. Tests made by N. E. Lewis, D. J. Irish, J. A. W. Dixon.

Date of test, 1908.	Oct. 20.	Oct. 29.	Nov. 5.	Nov. 10.	Nov. 25.	Dec. 5.	Dec. 17.
Duration of test (hrs.)	3	3.5	3	1	3	2	2
Steam pressure (lbs.)	228	225	223	232	226	222	225
Temperature of feed water (°F.)	60	95	98	89	52	47	48
Superheat in steam (°F.)	31	30	44	47	71	57	61
Pressure of oil at burners (lbs.)	239	228	222	222	193	193	196
Temperature of oil at burners (°F.)	190	206	195	195	214	207	206
Oil burned per hour (lbs.)	749	704	782	1,202	1,150	1,039	1,163
Oil per burner per hour (lbs.)	187.3	176.1	195.4	300.5	287.5	259.8	290.8
Oil per cubic foot furnace volume per hour (lbs.)	5.31	3.74	4.15	6.38	6.11	5.52	6.17
Oil per square foot heating surface per hour (lbs.)	.293	.275	.305	.470	.449	.406	.454
Draft in uptake (in.)	−.43	−.39	−.72	−.85	−.94	−.97	−.84
Draft in furnace (in.)	−.18	−.17	−.36	−.33	−.72	−.50	−.25
Blast at burners (in.)	.00	.00	.00	.00	+.67	.00	.00
Temperature of air in fire-room (°F.)	86	101	71	99	88	67	70
Temperature of waste gases (°F.)	504	546	550	654	639	574	573
Analysis of waste gases (p. ct.) CO_2	13.2	10.2	8.2	8.3	9.4	Apparatus, not working.	10.9
O	3.0	5.5	8.5	8.2	7.8		6.1
CO	0.0	0.0	0.0	Trace.	0.0		0.0
N	83.8	84.3	83.3	83.5	82.8		83.0
Water evaporated per hour from and at 212° (lbs)	11,502	10,806	9,889	16,137	16,225	16,524	19,121

TABLE I.—IDALIA TESTS—Continued.

Date of test, 1908.	Oct. 20.	Oct. 29.	Nov. 5.	Nov. 10.	Nov. 25.	Dec. 5.	Dec. 17.
Water per square foot heating surface per hour from and at 212° (lbs.)	4.49	4.22	3.73	6.30	6.34	6.45	7.47
Water per pound oil from and at 212° (lbs.)	15.36	15.34	12.65	13.42	14.11	15.90	16.45
Specific gravity of oil	.934	.934	.934	.934	.935	.935	.935
Flash-point of oil (°F.)	220	220	220	220	224	224	224
British thermal units per pound of oil	19,021	19,021	19,021	19,021	19,174	19,174	19,174
Efficiency (p. ct.)	78.0	77.8	64.2	68.1	71	80.1	82.8

Conditions:—

October 20: 4—$\frac{1}{32}''$ burners. C. I. cones admitting air through slots and front. Regular grate bars covered with ashes. Dark gray to black smoke at all times.

October 29: 4—$\frac{1}{32}''$ burners. Face of burners $1\frac{1}{2}$ inches inside face of cones. Grates lowered 9 inches. Boiler dampered for economy. Considerable smoke.

November 5: 4—$\frac{1}{32}''$ burners. Air through slots in sides of cones only, fronts closed. Smoke very dense.

November 10: 4—$\frac{1}{16}''$ burners. C. I. cones removed, and small tin funnels put on ends of burners. Considerable smoke.

November 25: 4—$\frac{1}{16}''$ burners. Flat air impellers, 4-inch hole in center and 23 wings. Smoke dark gray, growing lighter.

December 5: 4—$\frac{1}{16}''$ burners. Flat air impellers, two in center, 2-inch hole, 26 wings. Two at sides, 1-inch hole, 25 wings. Smoke from gray to light gray.

December 17: 4—$\frac{1}{16}''$ burners. Tip of burners 1 inch away from face of flat air impellers with 2-inch holes and 26 wings. No smoke.

Table II.—Wyoming. Official Tests with Coal.

Babcock & Wilcox boiler, 2,571 sq. ft. H. S., G. S. 57.3; ratio, 44.4 to 1; Pocahontas, hand picked coal.
Tests made by Commander C. W. Dyson, U. S. N.; Lieut.-Comdr. J. K. Robison, U. S. N.; Lieut.-Comdr. H. C. Dinger, U. S. N.

Date of test, 1910.	June 13–14.	June 14–15.	June 15–16.	June 16–17.	June 18.
Duration of test (hrs.)	24.06	24.5	24.0	24.0	3.0
Steam pressure (lbs.)	202	201.4	202.8	201.6	200.4
Temperature feed water (°F.)	211.6	211.4	207.8	204.1	194.4
Moisture in steam (p. ct.)	0	0	.086	.172	.43
Moisture in coal (p. ct.)	.88	.74	.74	1.06	.75
Dry coal burned per hour (lbs.)	873	1,425	2,039	2,379	4,036
Per cent refuse in dry coal by test	6.0	3.83	3.28	4.34	8.55
Dry coal burned per square foot of grate per hour	15.08	24.62	35.22	41.10	69.72
Draft in uptake referred to atmosphere (in.)	−.31	−.94	− .30	− .26	−1.84
Draft in furnace referred to atmosphere (in.)	−.16	−.46	+ .66	+ .91	− .79
Air pressure in fire-room referred to atmosphere (in.)	.00	.00	+1.41	+1.95	+3.00
Temperature air entering ash pit (°F)	94	98	86	94	106
Temperature waste gases (°F.)	491	545	602	628	659
Analysis of waste gases (p. ct.) CO_2	13.2	13.6	12.9	13.6	11.6
Analysis of waste gases (p. ct.) O	4.2	4.7	4.5	3.9	5.07
Analysis of waste gases (p. ct.) CO	0.5	0.4	0.5	0.8	1.09
Analysis of waste gases (p. ct.) N	82.1	81.3	82.1	81.7	82.24
Water evaporated into dry steam per hour from and at 212° (lbs.)	9,974	16,543	23,208	27,060	37,951
Water per square foot heating surface per hour from and at 212° (lbs.)	3.88	6.43	9.03	10.52	14.76
Water per pound dry coal from and at 212° (lbs.)	11.42	11.61	11.38	11.38	9.45

TABLE II.—WYOMING. OFFICIAL TESTS WITH COAL—Continued.

Date of test, 1910.	June 13–14.	June 14–15.	June 15–16.	June 16–17.	June 18.
Water per pound combustible from and at 212° (lbs.)	12.15	12.07	11.77	11.89	10.33
Efficiency based on dry coal (p. ct.)	72.50	73.70	72.24	72.24	60.00
Heat balance in per cent, calorific value of combustible—					
Absorbed by boiler (p. ct.)	74.39	73.95	72.06	72.80	63.25
Loss due to heat in waste gases (p. ct.)	11.09	12.24	14.63	14.20	16.31
Loss due to moisture in fuel (p. ct.)	.07	.06	.06	.09	.07
Loss due to burning hydrogen (p. ct.)	3.27	3.34	3.44	3.45	3.46
Loss due to incomplete combustion (p. ct.)	2.09	1.61	2.15	3.18	4.98
Various other losses including radiation and unaccounted for (p. ct.)	9.08	8.80	7.66	6.28	11.93

Table III.—Wyoming. Preliminary Tests with Oil.

Babcock & Wilcox boiler, 2,571 H. S.; Peabody mechanical atomizers; Texas oil, 18° Baumé; flash-point, 240° F.; B. T. U. per pound 19,100; closed fire-room; jet in stack.
Tests made by D. J. Irish.

Date of test, 1910.	Oct. 4.	Oct. 7.	Oct. 8.	Oct. 17.	Oct. 18.	Nov. 14.	Nov. 18.
Duration of test (hrs.)	3	3	3	2	2	1	2
Steam pressure (lbs.)	212	210	208	210	209	210	209
Temperature of feed water (°F.)	70	68	67	63	62	51	50
Pressure of oil at burners (lbs.)	196	198	203	200	211	142	210
Temperature of oil at burners (°F.)	182	182	181	181	181	192	183
Oil burned per hour (lbs.)	1,863	1,809	1,699	2,124	1,045	2,196	1,195
Oil burned per burner per hour (lbs.)	310.5	301.5	424.7	265.5	261.2	244	239
Oil burned per cubic foot furnace volume per hour (lbs.)	11.6	7.67	7.19	9.0	4.43	10.12	5.51
Oil burned per square foot heating surface per hour (lbs.)	.72	.70	.66	.82	.40	.85	.46
Draft in uptake—referred to atmosphere (in.)	− .60	− .63	−.70	−1.37	− .26	−2.74	−.43
Draft in furnace (in.)	—	—	—	—	—	—	—
Air pressure in fire-room referred to atmosphere (in.)	+2.60	+1.97	+2.55	+2.09	+1.32	+2.26	+.95
Temperature of air in fire-room (°F.)	98	—	—	—	—	—	—
Temperature of waste gases (°F.)	713	653	645	762	534	750	560
Analysis of waste gases (p. ct.) CO_2	10.7	10.7	10.3	10.9	11.5	9.9	11.1
Analysis of waste gases (p. ct.) O	5.7	7.6	5.5	4.4	3.6	—	4.1
Analysis of waste gases (p. ct.) CO	0.0	0.0	0.1	0.2	0.1	—	0.0
Analysis of waste gases (p. ct.) N	82.6	81.7	84.1	84.5	84.8	—	84.8
Water evaporated per hour from and at 212° (lbs.)	28,381	27,862	25,583	32,389	16,514	33,846	19,201

TABLE III.—WYOMING. PRELIMINARY TESTS WITH OIL—Continued.

Date of test, 1910.	Oct. 4.	Oct. 7.	Oct. 8.	Oct. 17.	Oct. 18.	Nov. 14.	Nov. 18.
Water evaporated per square foot heating surface per hour from and at 212° (lbs.)	11.04	10.84	9.95	12.59	6.42	13.16	7.47
Water evaporated per pound of oil from and at 212° (lbs.)	15.24	15.40	15.06	15.25	15.8	15.41	16.07
Efficiency (p.ct.)	77.05	77.86	76.14	77.10	79.88	77.91	81.25

Conditions:—

October 4: 6—$\frac{1}{16}$-inch burners, two in each of the three fire doors. Grate bars covered with fire brick. Six $9\frac{3}{4}$-inch diameter air impellers, 26 blades. Trace of smoke.

October 7: 6—$\frac{1}{16}$-inch burners set same as preceding test but grate bars removed and ash pit lined with fire brick. Light gray smoke.

October 8: 4—$\frac{3}{32}$-inch burners, 2 in center door, 1 in each side door, otherwise setting not changed. Smoke trace to light gray.

October 17: 8 burners in two rows 4—$\frac{1}{16}$-inch and 2—$\frac{1}{32}$-inch in upper row, and 2—$\frac{3}{64}$-inch in lower row. Otherwise setting not changed. Smoke variable, moderate to slight trace.

October 18: 4 burners in operation. 2—$\frac{1}{16}$-inch burners in upper row and 2—$\frac{3}{64}$-inch burners in lower row. Otherwise setting not changed. Trace of smoke.

November 14: Furnace front fitted with 11 cast iron boxes carrying 8-inch impeller plates. 9—$\frac{3}{64}$-inch burners in operation. Light gray smoke to smokeless.

November 18: Same as preceding except 5—$\frac{3}{64}$-inch burners in operation. Very light vapor of smoke.

Table IV.—Wyoming. Official Tests with Oil.

Babcock & Wilcox boiler, 2,571 sq. ft. heating surface; Peabody mechanical atomizers; Texas oil—lighter constituents removed. Tests made by Capt. C. A. Carr, U. S. N.; Lieut.-Comdr. J. K. Robison, U. S. N.; Lieut.-Comdr. John Halligan, Jr., U. S. N.

Date of test, 1910.	Nov. 28.	Nov. 28.	Nov. 29.	Nov. 29.	Nov. 30.	Dec. 3.
Duration of test (hrs.)	2	3	3	4	3	3
Steam pressure (lbs.)	210	210	211	212	215	215
Temperature of feed water (°F.)	168.6	160.9	201	211.2	185.6	182.8
Moisture in steam (p. ct.)	.81	.71	.16	.11	.22	.17
Pressure of oil at burners (lbs.)	191	189	176	131	153	172
Temperature of oil at burners (°F.)	175	183	184	210	199	196
Oil burned per hour (lbs.)	2,972	1,704	1,202	666	1,922	1,947
Oil burned per burner per hour (lbs.)	270.2	213	300.5	222	240.3	243.4
Oil burned per cubic foot furnace volume per hour (lbs.)	13.69	7.85	5.54	3.07	8.86	8.97
Oil burned per square foot heating surface per hour (lbs.)	1.156	.663	.467	.259	.747	.757
Draft in uptake—referred to atmosphere (in.)	−2.23	−.41	−.46	−.39	−.61	−1.15
Draft in furnace—referred to atmosphere (in.)	—	—	—	−.32	+.32	−0.01
Air pressure in fire-room—referred to atmosphere (in.)	+2.60	+1.69	+1.18	+.33	+1.97	+1.64
Temperature of air in fire-room (°F.)	71	75	70	79	79	76
Temperature of waste gases (°F.)	771	666	533	447	702	630
Analysis of waste gases (p. ct.) CO_2	9.85	9.26	11.57	11.86	10.71	10.94
O	6.46	7.68	4.50	4.08	5.18	4.73
CO	.01	.00	.04	.04	.02	.00
N	83.68	83.06	83.89	84.02	84.09	84.37

TABLE IV.—WYOMING. OFFICIAL TESTS WITH OIL—Continued.

Date of test, 1910.	Nov. 28.	Nov. 28.	Nov. 29.	Nov. 29.	Nov. 30.	Dec. 3.
Water evaporated per hour from and at 212° (lbs.)	40,712	24,494	18,895	10,569	27,149	30,064
Water evaporated per square foot heating surface per hour from and at 212° (lbs.)	15.83	9.53	7.35	4.11	10.56	11.69
Water evaporated per pound of oil from and at 212° (lbs.)	13.70	14.37	15.72	15.86	14.12	15.44
Specific gravity of oil	.932	.932	.932	.932	.932	.932
Flash point of oil (°F.)	295	295	295	295	295	295
British thermal units per pound of oil	19,291	19,291	19,291	19,291	19,086	19,086
Efficiency (p. ct.)	69.29	72.68	79.50	80.21	71.41	78.08
Number of burners in operation	11	8	4	3	8	8
Smoke on scale of 5	2.1	1.5	1.3	1.5	2.3	1.15

Table V.—Wyoming. Natural Draft Oil Tests.

Babcock & Wilcox boiler, 2,571 square feet heating surface; Peabody mechanical atomizers; Texas oil; 18° Baumé; flash-point 240° F.; B. T. U. per pound 19,100.
Tests made by D. J. Irish.

Date of test, 1912.	Jan. 17.	Feb. 7.	Feb. 14.	Feb. 24.	Mar. 7.	May 3.
Duration of test (hrs.)	2	2	2	2	1½	2
Steam pressure (lbs.)	195	201	197	191	195	195
Temperature of feed water (°F.)	48	37	40	40	40	52
Pressure of oil at burners (lbs.)	195	195	195	202	195	230
Temperature of oil at burners (°F.)	110	178	163	188	—	193
Oil burned per hour (lbs.)	588	734	922	1,114	1,192	743
Oil burned per burner per hour (lbs.)	195.8	244.7	307.3	278.5	238.4	186
Oil burned per cubic foot furnace volume per hour (lbs.)	2.7	3.3	4.15	5.01	5.36	3.35
Oil burned per square foot heating surface per hour (lbs.)	.23	.29	.36	.43	.46	.30
Draft in uptake (in.)	−.48	−.48	−.35	−.32	−.31	−.48
Draft in furnace (in.)	−.28	−.25	−.25	−.21	−.20	−.17
Temperature of waste gases (°F.)	460	510	525	525	535	529
Analysis of waste gases (p. ct.) CO_2	11.2	11.7	11.6	11.5	11.8	10.1
Analysis of waste gases (p. ct.) O	5.1	6.1	5.4	4.1	4.2	7.0
Analysis of waste gases (p. ct.) CO	0.0	0.0	0.0	0.0	0.0	0.0
Analysis of waste gases (p. ct.) N	83.7	82.2	83.0	84.4	84.0	82.9
Water evaporated per hour from and at 212° (lbs.)	9,124	11,329	14,909	16,932	18,355	11,650
Water evaporated per square foot heating surface per hour from and at 212° (lbs.)	3.31	4.1	5.4	6.15	6.66	4.23
Water evaporated per pound of oil from and at 212° (lbs.)	15.53	15.43	16.15	15.20	15.39	15.68
Efficiency (p. ct.)	78.51	78.01	81.65	76.85	77.81	79.27

Conditions:—
January 17: 3—$\frac{3}{64}''$ burners. Straight blade impellers 12″ diameter. Smoke ¼ scale of 5.
February 7: 3—$\frac{1}{16}''$ burners. Very wide blade impellers. Smoke ½ scale of 5.
February 14: 3—$\frac{1}{16}''$ burners. 13″ diameter impellers with blade cut away at ends to give more air at outer circumference. Smoke 2.
February 24: 4—$\frac{1}{16}''$ burners. 12″ diameter impellers. Ends cut away. Smoke 1½.
March 7: 5—$\frac{1}{16}''$ burners. 8″ diameter impellers, set in 13″ diameter opening. Smoke ¾.
May 3: 4—$\frac{3}{64}''$ burners. 13″ diameter impellers. End of blades cut away. Smoke ¼.

The boiler room of the United States Navy oil-tank ship Arethusa is shown in Fig 15, Plate 100, the two Babcock & Wilcox boilers replacing two double end Scotch boilers. This vessel is one of the first fitted with mechanical atomizers operating under natural draft.

SCOTCH BOILER INSTALLATIONS.

The round spray mechanical atomizer and impeller plate are well adapted for use in the corrugated furnaces of the Scotch boiler, and The Babcock & Wilcox Company has made installations for both natural draft

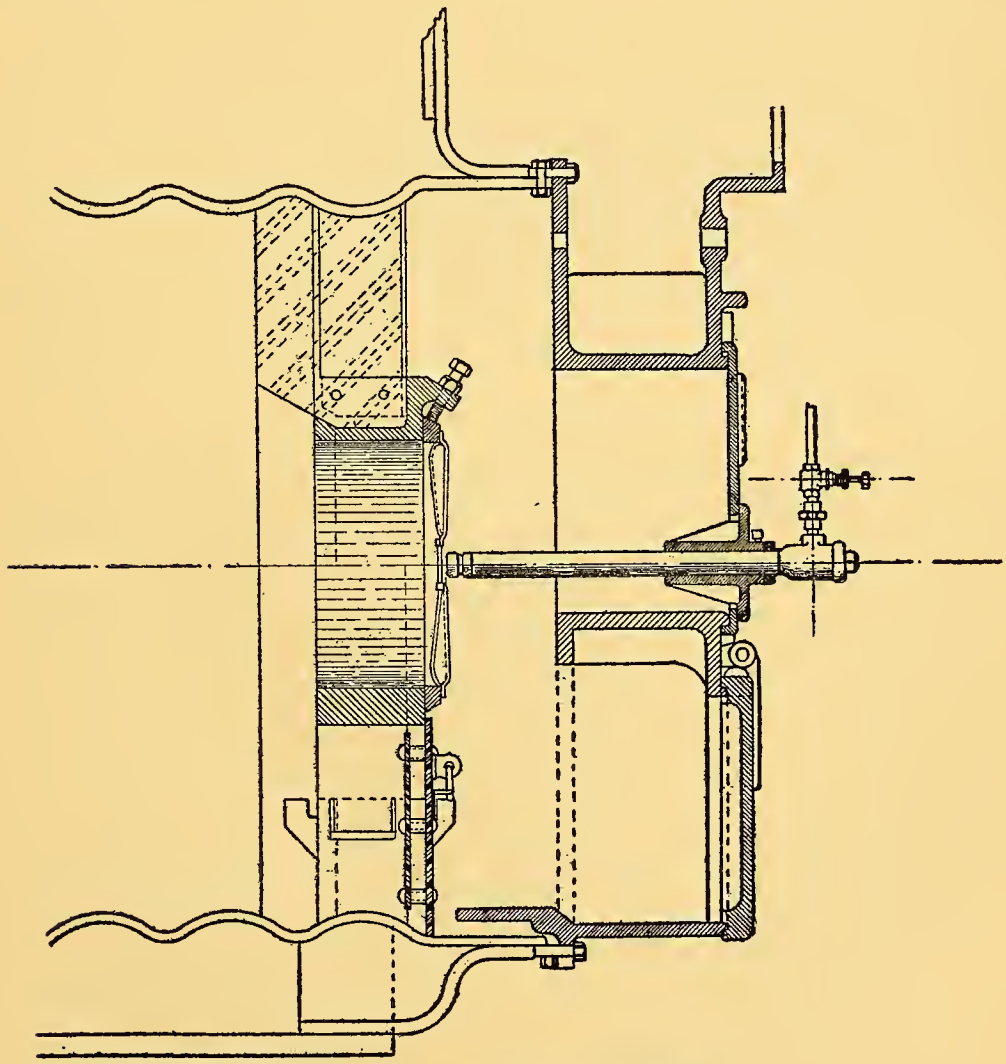


Fig. 16.—Herman Frasch Installation.

and Howden forced-draft vessels fitted with this type of boiler. Figure 16 shows the arrangement adopted for the steamer Herman Frasch, of the Union Sulphur Company, recently altered from coal to oil burning. This vessel is now developing an indicated horse-power on less than a pound of oil.

FLAT SPRAY ATOMIZERS.

Mention has already been made of the special advantages of this device, and the many forms of successful steam atomizers which give a flat flame warrant the belief that there is a wide field awaiting a thoroughly satisfactory flat spray mechanical atomizer.

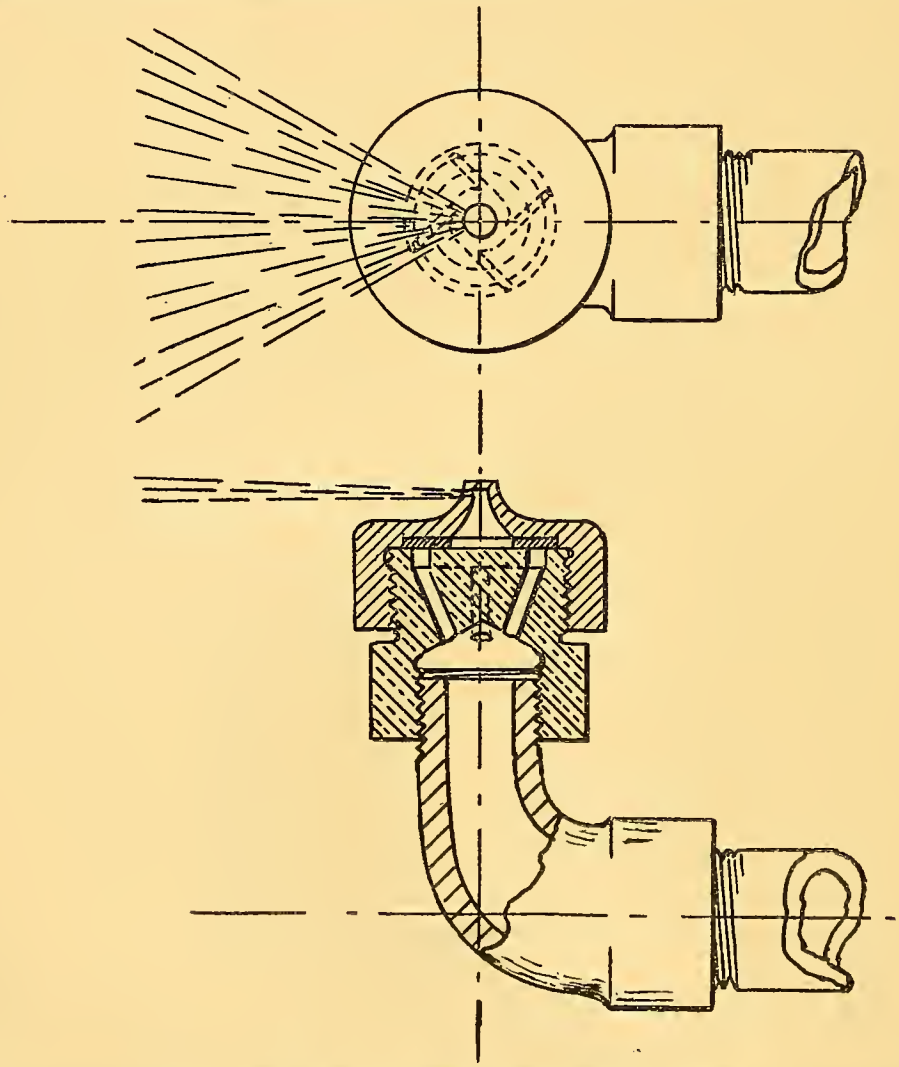


Fig. 17.—Peabody Flat Spray Mechanical Atomizer.

I have referred to a flat flame atomizer formed of two flat surfaces pressed together, and another consisting of two round oil jets striking

together. Neither of these schemes seemed to promise very much in the way of material for development. Another form which does seem to possess some merit, however, is illustrated in Fig. 17. This consists of a means for giving the oil a rapid whirling motion as in the case of the round flame burner and then releasing the liquid through a slot in the side of the tip in a plane at right angles with the axis of revolution instead of through an orifice concentric with the axis. It is apparent that centrifugal force will here come into action as an atomizing agent but that the spray will be flat instead of conical. So far as I know, the only flat flame mechanical atomizer which has been put on the market is that brought out by the Schutte-Koerting Company, and installed by them on the U. S. S. Utah. This burner is simplicity itself—a very considerable advantage—and the spray is excellent at low powers. About the only limitation which I have been able to discover in this burner is the fact that at anything over about 100 pounds of oil delivered per hour the spray loses its finely diffused character. The above installation was made under the direction of Mr. Luther D. Lovekin, a member of this Society, whose various successes in burning oil fuel are too well known to require any mention here. I feel sure that if Mr. Lovekin would give his attention to this attractive little flat flame atomizer he would be able to make it a real factor in the art.

AIR DISTRIBUTERS.

While I have indicated some of the various air-distributing devices used in the experiments above described, it seems advisable to group these together with illustrations of some of the principal types which have been tried out.

Great delicacy is required in introducing the air for combustion, very slight changes affecting the results in unsuspected ways, and while almost any method may result in smokeless combustion, maximum economy and capacity can only be secured by careful and intelligent design.

It is not necessary to give the air a whirling motion but, judging from our rather exhaustive experiments, better gas analyses are secured, lower air pressures are required, and less refinement of adjustment is needed if the air is brought into contact with the oil spray with the right sort of a twist. We have found the impeller plate illustrated in Fig. 11, Plate 97, most effective in accomplishing this mixture, and our most satisfactory results have been obtained with it.

We have, however, experimented with the following forms, some of which will be familiar to you:—

Fig. 18. Cast-iron truncated cone, with slots cored in the side so arranged as to give the air a whirling motion. It was tried with the end closed and all the air passing through the slots, and also with the end open, some of the air passing through the slots and some through the end of the cone around the burner. The burner was located at the end of the cone as shown in the cut, and also pushed in to the inner end of the cone, and also in intermediate positions. The whirling motion of the air obtained with this arrangement is of a different character from that obtained with the impeller plate.

Figs. 19 and 20. Truncated cones made up of concentric rings of sheet iron, with air passages between them, and so formed as to direct the air toward the axis. The angle of the first set of rings was $7\frac{1}{2}$ degrees and that of the second set, 15 degrees from the axis. No whirling motion.

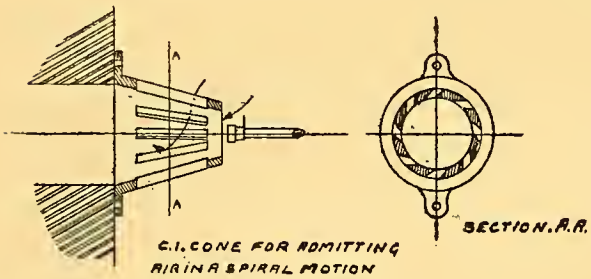
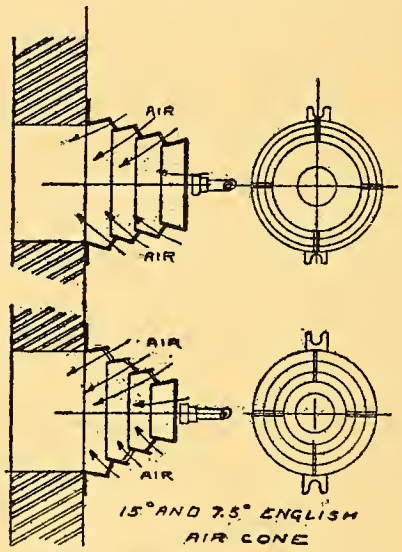


Fig. 18.



Figs. 19 and 20.

Fig. 21. Truncated cone of sheet iron, no air openings in the side but air admitted at both ends, as shown by the arrows in the illustration. No whirling motion.

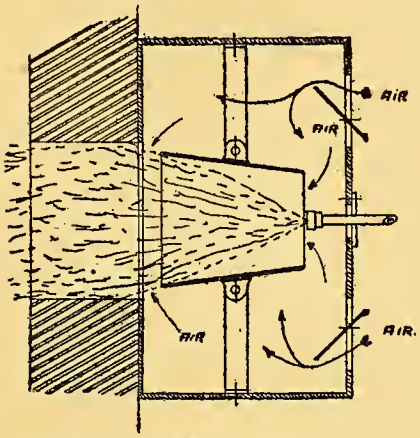
Fig. 22. Flat disc or plate of sheet iron placed on fire-room side of burner tip to produce effect of directing the air to the oil spray as shown by the arrows. Plate tried in various positions, also removed entirely. No whirling motion.

Fig. 23. Sheet-iron cone placed over burner tip to direct air to spray as shown. Tried in various combinations with regard to burner tip and opening to furnace. No whirling motion.

Fig. 24. Conical bladed air impeller, air given a whirling motion and directed in toward axis.

Fig. 25. Conical bladed air impeller, air given a whirling motion but directed away from axis; reverse of last figure.

Fig. 26. Venturi tube effect; air given a whirling motion by means of flat bladed air impeller. Large impeller set at large diameter at entrance of tube, and also in another experiment small impeller set at contracted diameter of tube.



SOLID W.I. CONE. WITH AIR. ADMITTANCE AS. SHOWN

FIG. 21.

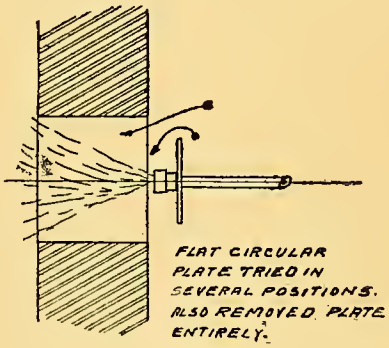


FIG. 22.

Fig. 27. Device for giving the air a whirling motion by delivering it in a plane at right angles to the axis of the burner, tangentially to an air chamber surrounding the burner tip. In this arrangement the air was given a whirling motion in a manner very similar to that by which the oil was given a whirling motion inside the burner.

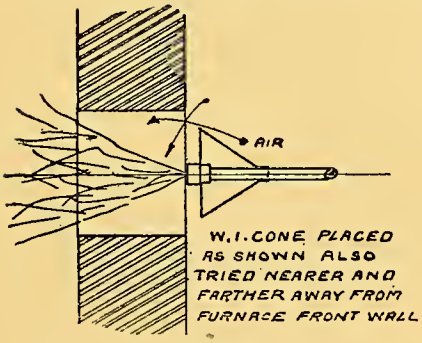


FIG. 23.

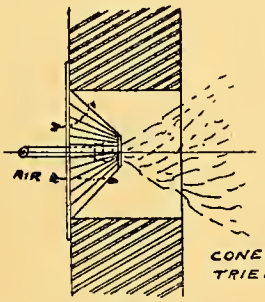


FIG. 25.

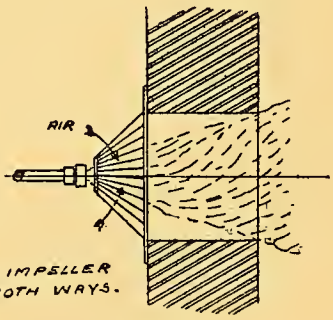
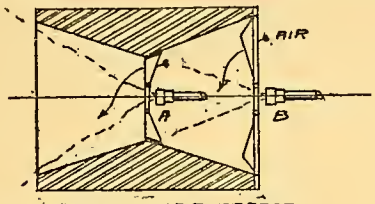


FIG. 24.

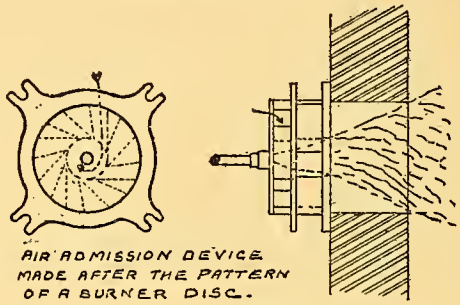
Fig. 28. Flat bladed air impeller giving the air a double twist, the outer blades driving it one way and the inner blades driving it the other. Also tried three sets of blades, the inner and outer sets driving the air in one direction and the middle set twisting it the other.

Fig. 29. Long horizontal slot admitting the air into a chamber enlarging toward the furnace; used in connection with the flat spray atomizer.



VENTURI TUBE EFFECT TRIED WITH IMPELLER AT POINTS A, B.

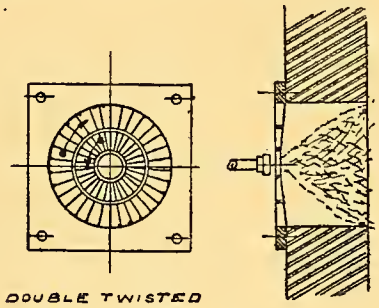
FIG. 26.



AIR ADMISSION DEVICE MADE AFTER THE PATTERN OF A BURNER DISC.

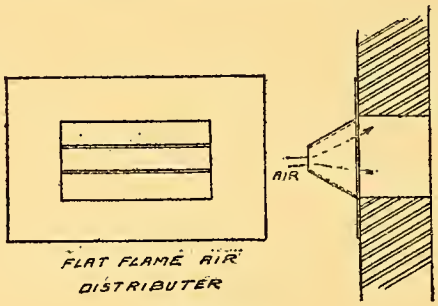
FIG. 27.

Fig. 30. Series of horizontal blades located on a flat plate over an area of circular form, the blades below the center driving the air upward and the blades above the center driving the air downward; used with flat spray burner.



DOUBLE TWISTED AIR IMPELLER

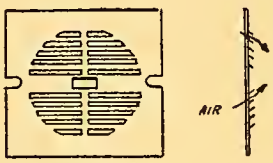
FIG. 28.



FLAT FLAME AIR DISTRIBUTER

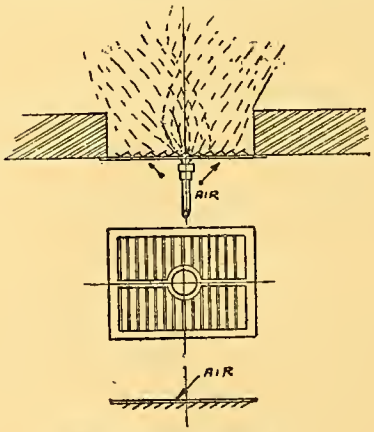
FIG. 29.

Fig. 31. Series of vertical blades on a flat plate of oblong shape, the blades below the center driving the air to the left and the blades above the center driving the air to the right; used with flat spray burner.



FLAT FLAME AIR DISTRIBUTER

FIG. 30.



DESIGN FOR FLAT FLAME IMPELLER WAS NOT SATISFACTORY

FIG. 31.

PRINCIPAL SYSTEMS USED.

This review of the subject of mechanical atomization of oil would not be complete without some reference to the principal systems which have been installed in our torpedo-boat destroyers and through the courtesy of the editor of the Journal of the American Society of Naval Engineers, I am able to reproduce illustrations of this apparatus which have been published in that periodical. I also extend my thanks to Mr. John Platt, Consulting Engineer; Mr. Chas. P. Wetherbee, Vice-President of the Bath Iron Works; Mr. H. Brown, Assistant to the President of the Fore River Shipbuilding Company; and the Schutte-Koerting Company for information relative to the apparatus in which they are interested.

Thornycroft (Fig. 32).—In this burner the oil receives a whirling motion

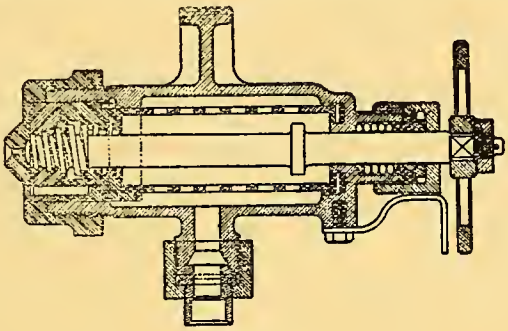


FIG. 32.

by passing through a spiral groove into a central chamber communicating with the outlet orifice of the tip. The tip fits on to a nozzle in which there is a cylindrical hole about the same diameter as the central chamber, and concentric with the axis of the burner. In the surface of this cylindrical hole a thread of square section is cut, of very slight depth at the end coinciding with the central chamber in the tip, but increasing rapidly in depth toward the direction of the opposite end of the burner, at which the oil is admitted. A spindle fits into the cylindrical hole of the nozzle and on this spindle there is a corresponding thread, accurately fitting the thread of the nozzle and tapering to practically nothing at the end. When the spindle is screwed home the thread on the spindle bottoms on the tapered thread of the nozzle and no oil can get to the tip. As the spindle begins to be unscrewed, however, the marked taper of the two threads causes them to separate and form in combination a spiral groove, the sectional area of which rapidly increases as the spindle continues to be unscrewed. The central chamber is formed by the combination of the end of the spindle and the burner tip. The output of this burner is controlled by the revolution of the spindle which regulates the area of the spiral oil passage.

The air for combustion is admitted through annular openings formed between concentric rings or short cylinders strung together to form a sort of truncated cone, somewhat similar to the device shown in Figs. 19 and 20, except that the air is not directed toward the center.

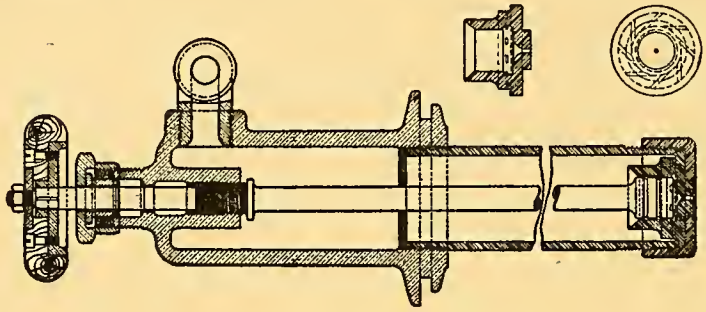


FIG. 33.

Normand (Fig. 33).—Eight small ducts deliver the oil tangentially to the central chamber formed by the combination of the tip and an adjustable spindle. The chamber is recessed so that the movement of the spindle does not in any way close or affect the ducts, its office being, besides forming one wall of the chamber, to close or throttle the outlet orifice. In this burner the ducts and outlet passage and orifice are made in a single piece which is held to the pipe or body of the burner by a clamp.

The air-distributing device or tuyere consists of a truncated cone of sheet iron fitted on a portion of its surface with blades for giving the air a whirling motion (Fig. 34).

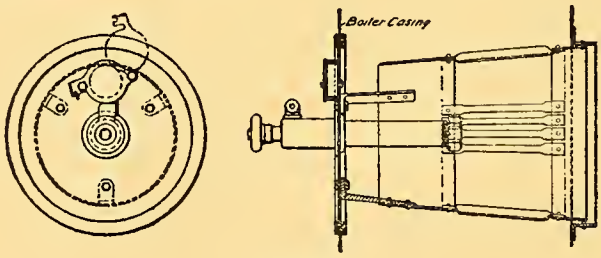


FIG. 34.

Schütte-Koerting (Fig. 35).—The tip of this burner is chambered out to receive a small spindle, less in diameter than the chamber except at the end, which is provided with a triple parallel thread which just fits the chamber and forms with the surface of the chamber three helical passages which deliver the oil to a smaller chamber at the end of the spindle, communicating with the outlet orifice. The spindle is not adjustable, the burner capacity

being varied entirely by controlling the oil pressure and temperature. This burner is fitted with a yoke and hand screw which holds it in position and provides a ready means for disconnecting.

The air distributer is a truncated cone provided with longitudinal slots or openings which may be varied in area by means of a cover or register revolving on the outside and regulated by suitable mechanism. The air does not receive a whirling motion, the mixture with the oil spray being obtained by carrying a high air pressure and forcing it through the restricted area of the slots at high velocity (Fig. 36, Plate 98).

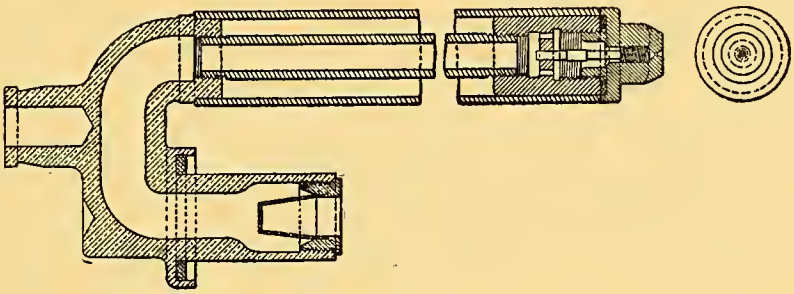


Fig. 35.

Fore River (Fig. 37).—An adjustable spindle in this burner is arranged to throttle or close the outlet orifice and to vary the size of the central chamber to which the oil is delivered through two tangential ducts, and the burner is provided with a quick detachable arrangement for holding in place.

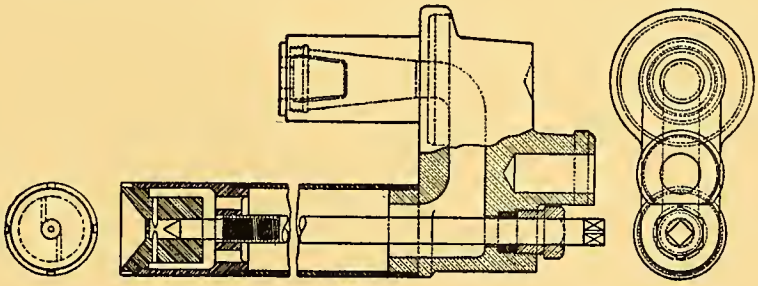


Fig. 37.

The air distributer is a cone provided with air slots in the side which give the air a whirling motion, the area of these slots being controlled by regulating mechanism. The angle of the cone is about 60 degrees, which is much greater than that of any of the designs above described, and another difference lies in the fact that all the air enters through the slots and none around the burner. The slots, besides being so arranged as to give the air a whirling motion, are greater in area in the direction of the furnace.

CONCLUSION.

In the preceding pages I have tried to show that while the problem of oil burning presents some difficulties, particularly as regards admission of air, there is very far from being any mystery about the matter. A strong leaning toward simplicity, "horse sense," and some experience, are a combination reasonably sure of giving good results, and I am not one of those who believe in very much abstruse reasoning or higher mathematics as a necessity. On the other hand oil is not water, and the manufacturers of water sprinklers who have recently, under the stimulus of the times, entered the field of oil burning and steam generation, will find something more required than a table of steam properties and a few analyses of oil, and will certainly learn the fallacy of the theory that "It's all in the nozzle"—and a poor one at that.

Improvements will be required and will be forthcoming, particularly in connection with spraying the heavier oils, and I look to the flat spray atomizer as a promising field for development. Meanwhile the results already attained are certainly encouraging.

In closing I want to say one word of appreciation of the work of my associate, Mr. David J. Irish, who made so many of the tests referred to above. It was through his ingenuity and originality that our flat impeller plate was developed, and his enthusiasm and industry in carrying out the long and arduous series of experiments undertaken by The Babcock & Wilcox Company were a most important factor in the success of the work.

DISCUSSION.

The Chairman:—Gentlemen, the paper on "Developments in Oil Burning," by Mr. E. H. Peabody, is now open for discussion.

Mr. Walter M. McFarland, *Vice-President:*—I do not intend to discuss the paper, but merely to say a word which Mr. Peabody's modesty has kept him from saying. As his associate I have known of the work which he has done, and have a great deal of admiration for the skill, ingenuity and ability which he has displayed in developing this oil-burning apparatus. The point I wish to make is simply for the benefit of the Society—it may seem to some on reading this paper that in some cases he has dismissed certain methods in a very cursory way which was rather too brief a treatment. The fact is that Mr. Peabody has

been working under very high pressure to get this paper before us at all; he had to work at night and on Sundays on it, and he did not have time to go into the details and explain all these matters. The conclusions Mr. Peabody gives in this paper are not to be taken as a mere *ipse-dixit* but they are the result of an unusually wide experience, and of investigating mistakes which have been made in previous practice. The statements given in the paper are based on conclusions gained in this manner, and it is due to Mr. Peabody to have that understood. I am sure you will agree that the paper is exceedingly valuable, and supplies in convenient form a lot of information we have all wanted to get for a long time.

THE CHAIRMAN:—I am sure that Mr. Peabody understands, and I hope other gentlemen who are to present papers will understand, that any suggestion of brevity from the Chair, as to brevity of presentation, is for the purpose of providing sufficient time in which to have the following papers presented. No one appreciates, I think, more keenly than the Chair that the preparation of a paper of this kind involves a great deal of work, and it is just such papers that add to the real value of the Proceedings of this Society. While these papers may not be read in full during the meetings of the Society, they are invariably read afterwards, and we are all intensely appreciative of the earnest work done by authors of papers such as this.

I am sure you will permit me, on behalf of the Society, to extend the thanks of the Society to Mr. Peabody for his most admirable paper.

The next paper to be presented will be that entitled "The Sperry Gyro-Compass in Service," by Mr. R. E. Gillmor.

Mr. Gillmor presented the paper.

THE SPERRY GYRO-COMPASS IN SERVICE.

By R. E. Gillmor, Esq., Associate.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

To be in service an instrument such as that with which the paper deals must have passed the experimental stage—the stage of trial and development. It must have emerged from that stage in a form which is fundamentally sound and practicable. It must have demonstrated its value and have been placed in actual service.

That this has been accomplished is well proven by the fact that the Sperry gyro-compass is now in service on six battleships and two submarines of the United States Navy, and by the fact that the Bureau of Navigation has awarded the same company a contract for ten additional complete compass installations.

The approximate, magnetic compass, with its many errors and weaknesses, is being superseded by an accurate instrument which gives us our true course at sea, is unaffected by magnetic or physical forces tending to deviate it, is simple and substantial, requiring little care or supervision.

Mariners have so long depended on the magnetic compass that many of them fail to realize the importance of the development of the gyro-compass. An analysis of the present-day methods of navigation shows clearly that ships using the magnetic compass do not steer the shortest course between the points of departure and destination. The magnetic compass serves to place them on approximately the correct course from point of departure and serves to give the helmsman a means of holding to an approximate average of this course. Because of the lag of the compass, it is necessary for the helmsman to use more helm than really necessary; and because the error of the compass is not exactly known, the ship is not held on the shortest path between the points of departure and destination. From time to time the position must be checked by observations and the course modified to correct for variation from the correct course. A greater distance than necessary is traversed because: (1) the helmsman is steering a serpentine course, and (2) because the average course steered is not the correct course and must be checked from time to time and modified to bring the ship to her destination. The errors so introduced are small but on a long voyage result in considerable loss of time and fuel. If observations of the sun or

stars cannot be obtained, due to fog or other atmospheric conditions, navigation in the vicinity of land becomes dangerous when using the approximate magnetic compass.

The development of the gyro-compass will obviate the necessity for studying the volumes on the theory of deviation of the magnetic compass and the methods for determining its numerous coefficients, the nightmares of the navigator. It will also be an end to the elaborate and time-consuming evolution known as swinging ship and compensating.

On ships of war the magnetic compasses in the conning tower, steering engine-room and other battle stations are of little use for steering the ship because of their extreme sluggishness due to the surrounding masses of magnetic material. The development of the gyro-compass and its secondary transmission system makes it possible accurately to navigate and maneuver the ship from any of these battle stations. Because the secondary transmission stations are portable, it is possible to establish temporary battle stations in lee of turrets or in other protected positions and use the telephone for controlling the movements of the helm. As the master compass, or heart of the gyro-compass system, is so effectually protected against gunfire as to prevent its destruction without sinking the ship, it provides a means for accurately handling a ship throughout an engagement and for navigating it into port after the engagement.

In this instrument we now have a compass that will really fulfil Victor Hugo's characterization of it as "the soul of the ship."

The necessity for eliminating chance is an imperative law which is fundamental to progress in every science.

What an important and wonderful advance has been made in the perfection of the gyro-compass. The guidance of our ships at sea has been dependent upon the uncertain magnetic force of the earth. This accurate instrument frees us from this dependence and gives us a means of precision for guiding and protecting our ships and the millions of people which they carry.

The French physicist Foucault was the first to analyze the phenomena of the gyroscope which underlie its application as a compass. This he did in 1851 when he used the gyroscope for demonstrating the rotation of the earth. His efforts resulted in the deduction of two laws which bear directly on the use of the gyroscope as a compass: first, that the inertia of a rapidly rotating wheel, suspended with freedom to move about all axes, is relative to space, and consequently that a gyro suspended in that manner will maintain its plane of rotation in space; second, that a gyroscope suspended with its axis of rotation horizontal, and with freedom about the horizontal axis partly or

wholly suppressed, will tend to process, or turn, about the vertical axis in an effort to place its plane of rotation coincident with that of the earth. The question of utilizing this phenomena in an instrument which would seek and maintain the true north and south meridian, regardless of position, speed or course or oscillating movements of the body on which it was mounted, involved a great many problems.

Early in his work, Mr. Sperry became convinced that the major problem was one of pure engineering in devising a suspension which would be frictionless about the vertical axis, allowing the gyroscope to turn with perfect freedom in its effort to seek the meridian.

In the most powerful gyroscopic compass which has ever been devised, the maximum directive force (axis at 90 degrees from the meridian) exerts a power which is equivalent to only .015 watt-seconds. In this connection it is interesting to note that even though the directive force is minute, it is approximately three hundred times that of the Navy standard magnetic, ten times that of any other gyroscopic compass, and fifteen hundred times that of the magnetic compass when placed in the same location in the ship. The directive force decreases in proportion to the cosine of the angle which the axis makes with the meridian until, when the axis is exactly on the meridian, the directive force is zero. The suspension must be such that the gyro is free to return to the meridian under the very minute directive force exerted when the axis has left the meridian by only a small fraction of a degree.

The solution of this problem alone involved years of experimental work, inasmuch as no ordinary suspension could be used because of the weights involved. The problem was finally solved by suspending the gyroscopic, or sensitive, element from a stranded wire, the top of which is carried in a frame surrounding the gyroscopic element, this frame being oriented by an electrical follow-up system in such manner as to cause the frame to follow any tendencies of the gyroscopic element to move about the vertical axis. This constitutes a highly frictionless suspension with the result that, while great power is available for driving the compass card and repeater transmitting system, the gyro itself has extremely little work to do and consequently can be made very sensitive while running at quite moderate speed. This suspension has made possible a strong, durable, and very accurate instrument.

Numerous other problems, quite as difficult of solution, were encountered. Perhaps the most difficult of all was that involved in so suspending the sensitive element that it would be unaffected by acceleration pressures arising from movements of the vessel on which it was mounted. In developing this point it was necessary to collect a large amount of data relating to

the time taken by all classes of vessels to accelerate from one speed to another. From this data the acceleration pressures were calculated and actually applied to the experimental instrument by means of weights allowed to act for a certain length of time.

The manner in which all of these problems were solved and the strong and accurate instrument which is the result can best be explained by reference to Fig. 1, Plate 101, which is a part section in the plane of the gyro wheel. The wheel itself rotates on the axis *A*, which is carried in a special type of ball bearing in the casing *B*. Casing *B* is in turn carried on the horizontal axis *C* in the ring *D*, which is called the vertical cardan ring. The vertical ring *D* is suspended by the stranded wire *E* and is guided about the vertical axis by the steadying bearings *F–F*. The top of this suspension wire is held in a frame which surrounds the sensitive element. Attached to this frame and integral with it is a ring *G* which surrounds the vertical cardan ring. This is termed the "phantom" ring because it is made to follow all tendencies of the cardan ring to move about the vertical axis. This upper frame, which surrounds the sensitive element, is mounted to swing in gimbal rings in the manner that is familiar in connection with magnetic compasses. Attached to the vertical cardan ring, and projecting through holes in the phantom ring, are posts, not shown in the figure. On these posts are carried small silver wheels which rest on a flat commutator carried in the movable frame of the compass, of which the phantom ring and suspension head are integral parts. This commutator has two silver segments insulated from each other by a narrow piece of mica. When the frame and sensitive element are both at rest, the silver trolley wheels attached to the posts on the vertical cardan ring rest on both of these silver segments, thus energizing both sides of the relay controlling the movements of the azimuth motor *M*, the purpose of which is to drive the frame about the vertical axis. If the gyro tends to move about the vertical axis these trolleys are moved off the insulating segment and on one of the silver segments, thus energizing the motor *M* in such manner as to cause the frame, phantom ring, compass card and repeater transmitter to follow the gyro. It can be seen that the top of the suspension wire is always moving to follow the bottom, so that the wire is virtually torsionless and the suspension frictionless about the vertical axis.

Swung in trunnions in the phantom ring, and passing through the vertical cardan ring but not touching it, is the bail or pendulum *R*, which is attached to the gyro casing at the point marked *S*. The vertical cardan ring is of such depth at the bottom as to permit the bail to swing freely through it. The phantom ring is at all times held rigidly in position with reference to the binnacle, although it is at the same time free to move around the vertical axis.

At the same time the phantom ring stands in practically constant relation to the gyro wheel and the moving element of the compass proper. The bail or pendulum R serves as a yielding connection between the gyro casing and the phantom ring, providing a means of suppressing freedom about the horizontal axis when the compass is off the meridian and the rotation of the earth has caused that axis to incline out of the horizontal. The bail being attached eccentrically to the vertical axis serves to partly suppress freedom about that axis, thus damping the oscillations of the gyro to bring it to the meridian by the shortest path. Further, since the phantom ring G stands in constant relation to the casing B, but is none the less independent from it, this ring forms the base from which movements may be made to produce a positive orientation of the wheel. At any position on the earth's surface except at the equator, the earth's rotation has a vertical component, its action being such as to tend to leave the north end of the axis of the gyro on the east side of the meridian. When the axis is left behind the meridian a portion of the tangential component of the earth's rotation causes a tilt which introduces the gravity couple of the pendulum about the horizontal axis. Simultaneously with this the couple about the vertical axis is also introduced, tending to destroy the couple about the horizontal axis. For every latitude there is some position of lag behind the meridian at which the couple about the vertical axis just maintains the axis of rotation at a tilt such that the couple about the horizontal axis can cause the necessary precession to follow the vertical component of the earth's rotation. A northerly or southerly component of the ship's speed acts to change the apparent direction of the earth's rotation, so that the resting position of the axis of the gyro varies with change in speed and course of the ship on which it is mounted. The variation of lag behind the meridian for variation of latitude and variation in course and speed of the vessel make it necessary to correct the axis of the gyro in accordance with the equation—

$$D = \frac{a\,K \cos H}{\cos L} - b \tan L,$$

in which a and b are constants, K is the speed, H the course and L the latitude. This correction is automatically solved and applied to the compass by means of a mechanical device, shown in Fig. 2, Plate 101, which when set for approximate speed and latitude constantly corrects the lubber's point of the compass card and the repeaters in such manner that the headings shown are always referred to the true geographical north.

Whenever the gyro is off the meridian its axis will incline by reason of the earth's rotation at a rate proportional to its angular distance from the

meridian; the sensitive element of the gyro is peculiarly suspended with three degrees of freedom independent of the compass card, so this inclination of the axis will take place independently from the compass card, which is always in a horizontal plane by reason of its gimbal ring suspension. These facts give us a means for finding the meridian independently of the compass card. The device used is a level, attached to the gyro casing or sensitive element, and capable of adjustment for latitude in such manner that the bubble of the level will always be in exact center when the compass is on the meridian. Any deviation from the meridian can be noticed by a change in the position of the bubble almost before the deviation occurs, and in finding the meridian after starting up the compass it is only necessary to level the compass by impressing forces by the hand about the vertical axis, and as it inclines from the horizontal count the number of divisions which the bubble passes in one minute; this multiplied by a known factor gives approximately the number of degrees which the axis of the gyro is from the meridian. Knowing this, the compass may be placed on the meridian by impressing a force downward on the end of the axis which is inclined up from the horizontal.

An alarm is supplied which sounds when current is removed from the main system supplying the gyro motor, when current is removed from the low voltage system supplying the azimuth motor and repeaters and when any serious oscillation of the compass occurs.

Recent severe tests of the Sperry gyro-compass have shown that the speed of the wheel need not be kept constant to hold the axis of the gyro on the meridian. By numerous tests it was found that power could be removed from the gyro wheel and that absolutely no variation would occur until the speed of the wheel dropped from 8,600 to as low as 5,000 revolutions per minute. This drop of speed would cover a period of approximately one and one-half hours. This development is very important to the use of the gyro-compass inasmuch as it obviates the necessity of keeping the voltage of the supply constant and makes it certain that the compass will be useful for at least one hour in case the current supply is removed by damage to the dynamos or by any other cause. In case of failure of the direct current supply, the 20-volt system is automatically energized by storage battery so that the follow up, and repeating compass systems will continue to operate for a period of at least ten hours.

It can be seen from Fig. 1, Plate 101, that the construction of the compass is strong and durable and that there are no parts requiring expert supervision or attendance. In fact the only parts of the master compass which require any degree of care are the silver trolleys and segments on which they make con-

tact for energizing the azimuth motor. These contacts and segments are provided in duplicate so that while the compass is running they may be removed and cleaned one at a time. The master compass is placed in a protected position well below the water-line and auxiliary compasses, known as repeaters, are provided at the wheel, in the steering engine-room, in the conning-tower, or at any point desired in the ship. The cards of these repeater compasses are driven by small six-pole motors, the poles of which are energized in succession from a transmitter on the master compass. The frame of the master compass is so geared to the transmitter that each one-sixth degree movement of the master compass is reproduced in the repeater.

Because of the simple mechanism involved, these repeaters can be made durable and substantial, requiring less care than is given a well-made clock. A dynamotor dynamo is provided for furnishing current for driving the compass wheel by means of an induction motor and for supplying the repeater system with low voltage current. The repeaters are also provided with cutout switches controlled from below, and with means for synchronizing them with the master compass.

Figure 3, Plate 102, is a photograph of the master compass with covers removed. The dials for setting the automatic correction device will be seen in the center at the top.

Figure 4, Plate 102, is a photograph of the master compass with top cover removed.

Figure 5, Plate 103, is a view of the master compass from above.

Figure 6, Plate 103, is a view of a portion of the master compass showing a correction applied to the lubber's line. The position of the small black pointer on the scale just above the correction dials shows the amount of the automatic correction which is being applied.

Figure 7, Plate 104, is a photograph of the wheel casing and vertical supporting ring. The two posts which carry the silver trolley wheels may be seen at the top. This photograph also shows the suspension wire and the levels referred to before. The space between the lower part of the casing and the vertical ring is allowed for the pendulum or yielding connection.

Figure 8, Plate 105, shows the gyro wheel and bearings, also the stator of the three-phase induction motor for spinning the wheel. The internal periphery of the wheel itself constitutes the rotor.

Figure 9, Plate 104, is a photograph showing the phantom ring which is made to surround the sensitive element and which is driven by the azimuth motor to follow all tendencies of the gyro. On this ring is mounted the compass card as shown, and in the center is the suspension head for supporting the sensitive element.

Figure 10, Plate 106, is the binnacle type of repeater.

Figure 11, Plate 107, is the energy supply switchboard.

Figure 12, Plate 107, is the cutout and synchronizing switchboard.

The perfection of an instrument such as the gyro-compass is seldom, if ever, accomplished through the efforts of one man alone. The master mind who conceives the idea must depend upon his associates for much of the work of development, and the speed and efficiency with which this development is accomplished rests to a large extent on the efficiency of the assistants. In this connection Mr. Sperry wishes me to express his appreciation of the efforts of Mr. H. C. Ford, whose efficiency has contributed much to the perfection of the Sperry gyro-compass.

The first compass was installed on board the Old Dominion Line steamship Princess Anne. It was placed at the farthest possible point from the ship's metacenter so as to obtain the maximum effect from the rolling and pitching of the vessel. A voyage was made with the compass from New York to Norfolk and return. During this time the ship rolled as much as 26 degrees on each side of an even keel. Close observation of the compass failed to disclose the slightest deviation due to this motion. Tests were made by quickly changing course and speed to ascertain whether or not any oscillations were induced by the acceleration pressures so impressed.

The results of these tests were very satisfactory and so encouraging that Mr. Sperry began negotiations with the Navy Department with a view to installing the compass on some naval vessel for an official trial. The progressive and far-seeing officers of the Compass Office immediately concluded to install the compass on the U. S. S. Drayton, a torpedo-boat destroyer. The trials on the Drayton served to convince the officers of the Compass Office that the instrument was practicable and that it had a great many advantages. It was then installed on board the U. S. S. Delaware, which was at that time the largest and most modern battleship in the world, the ship which had the honor of representing the United States at the coronation of His Majesty King George V. The author was then the officer in charge of electrical machinery and apparatus on board the Delaware and the compass was placed under his care. This circumstance resulted in the author becoming so interested in the work of the Sperry Gyroscope Company that he left the Navy a few weeks ago to become one of the engineers of that company.

The trials of the first compass on the Delaware extended over a period of three or fourth months, during which time it was found that in spite of the fact that the instrument on the Delaware was the first ever constructed and necessarily somewhat crude, it fulfilled its purpose wonderfully and was of the greatest service not only in target practice and battle maneuvers but

also in the navigation of the ship. No difficulty was experienced in keeping it in fine running order. In fact the electrician who was charged with the care of the apparatus had also to give his time to keeping in order all of the fire-control and telephone systems on the ship. A few minutes a day devoted to the compass were all that were necessary. After the compass had been in operation on board the ship for two or three months, Mr. Sperry came aboard to inspect it and to observe its operation in target practice. During that time complete tests were made of the operation of the instrument under shock of gunfire, rolling and other disturbing influences, with satisfactory results in every case.

The satisfactory performance on the Delaware resulted in a contract for supplying the Navy with eight complete gyro-compass outfits. These were installed on board the U. S. S. North Dakota, Florida, Utah, Michigan, Arkansas, and Wyoming, and on the submarines E-1 and E-2.

The design of these instruments differed quite considerably from that of the experimental compass. They were installed under the supervision of Mr. Sperry and his engineer, Mr. Ford, and were kept under constant observation so that any defects which might develop could be corrected and the design of the instruments so changed as to prevent the recurrence of the defects. Because of the necessary small changes in the instruments it was impossible to issue instructions as to their care and adjustment. For this reason these first compasses labored under a considerable handicap. Consider, for instance, what the fate of the magnetic compass would be if it were placed on a steel ship where those in charge of it knew nothing of its theory or the methods used for its compensation. This was the position in which the first gyro-compasses were placed. So far as the ultimate development of the instrument is concerned, this handicap served a useful purpose by developing an instrument requiring no expert knowledge and no attendance. However, notwithstanding the fact that the instrument was new and those in charge of it had no means of learning much about it, it was successful from the first.

Of course many small defects developed in the operation of these first eight instruments. None of these defects was fundamental in character and they were all corrected as soon as they occurred. In the latest instruments every one of these defects has been completely eliminated.

With very few exceptions it was found that by devoting ten or fifteen minutes a day to the compass it could be kept in perfect condition and could be used as a reliable navigating instrument to the exclusion of the magnetic compass.

One of the officers of the U. S. S. Florida told the author of an incident

which happened while coming into the harbor of New York which serves to illustrate one of the many advantages of the gyro-compass. This officer happened to be on the bridge when the ship was off Block Island and steaming toward the entrance to New York Harbor. The captain was on the bridge and conning the ship. Upon laying out the next change of course he found that it would be "6 true;" so he merely said to the officer of the deck "6 by gyro," and the officer of the deck gave the course to the helmsman, no calculation being necessary, as the helmsman had before him a repeater compass.

Suppose the captain had wished to change the course, using the old magnetic compass. If the compass rose of the chart had been marked relative to true north it would have been necessary for the navigating officer to have first applied the variation at that latitude, having corrected the variation for the elapsed time since the chart was printed, then apply this variation to the true course to obtain the magnetic course, and, with this magnetic course as an argument, look in the deviation tables for the deviation of the compass at that heading. This deviation would be marked "East" or "West," and in applying it to the magnetic compass to obtain the course by standard compass the navigator would have to think carefully as to which way it should be applied, imagining himself at the center of the compass card, applying westerly deviation to the right and easterly deviation to the left to obtain the compass course. Having obtained the course by standard compass, it would be necessary for the officer of the deck to climb to the standard compass, which on ships of the Florida type is located in the mast, about fifteen feet above the steering platform, and with his eyes on the standard compass he would have had to conn the helmsman to the proper course by standard compass, checking the course several times to be sure that no error was introduced by lag. Having found from the standard compass what the course should be by the steering compass, the officer of the deck would descend from the standard compass and report the ship on her course.

This is only one of the many valuable points brought out in practice. Perhaps the most valuable from the point of view of a naval officer are those which have to do with tactics. The pelorus dial can be made a repeater compass so that on line of bearing it is not necessary to call back and forth between the compass and the pelorus when getting the bearing of the flagship. Turning the vanes of the pelorus on the flagship and glancing at the card of the pelorus shows us immediately the true line of bearing. This feature is also of great value in taking bearings when navigating by land falls.

Many fleet formations in present-day tactics are on line of bearings and in maneuvering a fleet it is frequently necessary to change from one line of bearing to another. In using the magnetic compass for setting the pelorus,

or dumb compass, to obtain the line of bearing, many errors are introduced by the lag of the compass. As the gyro-compass has no lag whatever, this source of error is entirely eliminated by its use, and line of bearing formations can be kept with great accuracy.

All repeating compasses used are of the same type and consequently interchangeable. They may be mounted in gimbal rings or on the wall, ceiling or pedestal fixtures provided. Repeaters are illuminated from behind the dial; a small rheostat in circuit with the lamp makes it possible to obtain any desired intensity of illumination. The pelorus repeaters may be very faintly illuminated so that the light from the card will not interfere with obtaining bearings at night; the helmsman's repeater may be brightly illuminated so that all graduations of the compass card are distinctly visible from the wheel.

A comment made by one of the navigating officers using the Sperry gyro-compass serves to illustrate another important advantage. This comment was to the effect that since using the gyro-compass for navigating the ship he found little if any difference between the position of the ship by dead reckoning and the position by observation. The position by dead reckoning is that calculated from courses and distances run and is the position the ship should be in; the position by observation is that computed from observations of heavenly bodies or land and is the actual position of the ship. This difference is called "current correction," current being the scapegoat on which the delinquencies of the compass are fastened. In navigating a ship the calculated course is constantly modified as observations show it to be necessary. In other words, the ship is headed as nearly as possible on the proper course, and observations are taken to ascertain how far the ship is out of her course and how the succeeding course should be laid to arrive at the destination. This results in traversing a longer path than necessary, and in consequent loss of time and fuel. In foggy or cloudy weather the ship might get so far out of her course as to put her in a dangerous position.

With the gyro-compass it will be possible to navigate the ship accurately in any sort of weather and without taking observations to check the position. Observations would of course be taken in good weather as additional safeguard.

Navigating officers using the Sperry gyro-compass assert that the compass will entirely pay for itself within a year after its installation by the saving in fuel which will result from the use of an accurate compass having no lag.

The device heretofore referred to for determining the position of the meridian independently of the compass card has been found of much value

in service, not only in placing the compass on the meridian by hand when it is first started, but also for checking the compass at any time. A glance at the level on the sensitive element will tell the observer instantly as to whether the compass is on the meridian as even the slightest deviation of the compass will change the position of the bubble. The petty officer charged with the care of the compass on the U. S. S. North Dakota was very emphatic in stating that he didn't need to be told from aloft when the compass was on the meridian by observations of the sun; he already knew it by the position of the bubble in the compass level.

On the submarines having a gyro-compass it was found to be of the greatest value not only in navigating but in making an attack. By taking an observation of the ship to be attacked when seven or eight miles distant, the submarine can be run completely submerged and steered so accurately that it is possible to obtain exactly the right position for discharging torpedoes before rising to the surface for the final sight.

The title of this paper might convey some idea to the effect that the intention is to describe the methods of operation of the compass and experiences in its upkeep and adjustment. If the paper should treat of that alone its presentation would be hardly warranted because the operation and maintenance of the instrument is so very simple.

The installation of the instrument involves nothing complicated inasmuch as the only adjustment necessary is to properly place the lubber's point so that the true angular position of the ship's head is always shown.

In wiring and connecting up the instruments and switchboards, the usual navy standard wiring practice is always followed.

The starting of the instruments is merely a question of properly manipulating the facilities provided for accelerating the motor-generator. This occupies a time of approximately fifteen minutes.

The adjustment of the meridian by means of the levels has already been described. The only other adjustments necessary in handling the instruments are the adjustment for speed and latitude, made on the small dials provided for that purpose, and the adjustment of the head of the suspension wire, which is made by means of a tangential screw on this head, the object being to bring the sensitive element exactly in the center of its surrounding frame, or phantom ring, when the wheel is not spinning and the sensitive element is hanging as an inert mass.

A small pointer, placed on the trolley posts referred to above, exactly coincides with the black line on the block carrying the silver contracts when the suspension wire is in perfect adjustment.

In the daily operation of the compass the principal points to be observed are:—

(1) Avoid touching any part of the sensitive or gyroscopic element.

(2) Keep the silver contacts and trolleys in good working order.

(3) Keep the instruments and accessories clean and the circuits free from grounds.

The trials of the first eight instruments resulted in a contract for ten more compasses, the first to be delivered on October 1. The specifications for the instruments on this contract are very rigid. They provide that each set shall consist of a master compass, a motor-generator capable of generating both 130 volt A. C. current for the driving of the gyro wheel and 20-volt D. C. current for energizing the repeating system; a 40-ampere hour storage battery as auxiliary supply to the 20-volt system, arranged so that it floats on the 20-volt system at all times; switchboards; synchronizing and cutout switches, and four repeater compasses. The master compass is to contain an automatic correction for all heads and to provide adjustment for changes in speed and latitude. The level device, for showing the position of the meridian independently of the compass card, is required. All parts of the instrument are to be plainly marked to prevent any possible mistakes in assembling, adjusting or reading. Trolleys and contacts are to be provided in duplicate and must be so arranged as to be interchangeable. All gaskets to be unaffected by heat or by oil with which they might come in contact. The instrument must be provided with a means for automatically disconnecting the gyro motor from the motor-generator in case of failure of the D. C. supply to the motor-generator. This provision is made so that the motor-generator will have no braking effect on the gyro motor in case of failure of the D. C. supply. Provision is also made for an alarm bell so connected as to ring continuously in case of failure of the D. C. supply. All repeaters are to be of watertight construction and capable of immersion under a three-foot head of water for three hours without indication of leakage. The binnacle repeaters are to be provided with flexible cable and with a watertight connection box outside of the repeater itself so that the repeater can be disconnected and removed without the necessity of opening its case. All binnacle repeaters are to be illuminated from behind the compass card. Repeaters are to be furnished in binnacle type—that is, on a stand—or in wall type, for securing to bulkheads, as required. Repeater compasses shall be required to follow accurately the indications of the master compass at all rates of turning likely to be met after installation. A synchronizing panel is to be provided which shall be capable of setting any or all repeating compasses in exact agreement with the master compass, as desired. All electrical parts of the instruments

to be properly impregnated for protection against moisture and heat and to conform to the Navy's Specification for Auxiliary Electrical Appliances. The storage battery provided as auxiliary supply for 20-volt service shall be capable of supplying the azimuth motor, relay and all repeaters for a period of not less than ten hours. To be furnished with each set there shall be a complete folio of correct drawings of the instruments and three sets of instructions. The contractors are also required to furnish a full set of spare parts, accessories and tools, packed in a suitable and convenient case.

A rigid system of tests is provided for all instruments for determining whether or not the sets furnished conform to the specifications. These tests include the following:—

(*a*) Continuous running under conditions of heavy rolling, pitching and yawing for six days, during which time the deviation of the master or indications of the repeater compasses shall not exceed one-half degree from the correct indication; and during this time the vacuum shall not fall more than one and one-half inches.

(*b*) Continuous operation for forty-eight hours under condition of no vacuum, without excessive heating of any part and without any material increase in deviation from correct indication of the master or repeating compasses.

(*c*) Continuous operation for four hours at the critical speed, that is, at the speed where the natural period of the instrument synchronizes with the period of the wheel, thus causing vibrations. (On all of the latest instruments no critical speed has been found.)

(*d*) Speed test of the rotor of 10,000 revolutions per minute for two hours without effect upon the balance of the wheel. If the maximum speed that can possibly be given by the motor-generator equipment on board ship exceeds 10,000 revolutions per minute, then the speed tests shall be run at that maximum speed. The contractors shall certify that the rotor was run at least 12,000 revolutions for two hours before being finally balanced.

Contractors are required to furnish an engineer to supervise the installation and make adjustments on the sets installed. The instruments are to be guaranteed against any defects or imperfections for a period of one year.

Under the supervision of the Bureau of Navigation, the compass has been thoroughly tested on board the U. S. S. Worden and at the electrical laboratory of the Navy Yard of New York. During these tests several curves of the operation of the Sperry gyro-compass have been developed and these curves are published with the permission of the Bureau of Navigation.

Figure 13, Plate 108, is a time and speed curve, showing the rate at which the gyro wheel is accelerated when starting. This figure also shows a decel-

eration curve, taken in stopping the wheel by reversing the power to the gyro motor. If allowed to run without braking, the wheel would continue to rotate for approximately four hours and, as before stated, would hold the meridian for about one hour.

During the past summer a board of naval officers, of which Lieutenant Commander Miller was the senior member, was convened for the purpose of testing all phases of the actions of the compass in service. These tests were carried out at sea on the U. S. S. Worden.

Tests under roll and pitch demonstrated conclusively that the compass is free from the slightest oscillations due to the forces so impressed.

The board wished to particularly test the compass with a view to determining what oscillations, if any, would be introduced by the most severe changes of the speed and course of the vessel on which it is mounted.

The results of this test can be seen from Fig. 14, Plate 109. The changes in speed and course were so timed as to impress acceleration pressures at exactly the right point for causing the maximum increase in oscillation. As will be seen from the figures, the maximum amplitude of oscillation from the meridian was three-fourths of a degree. This three-fourths of a degree is really the summation of three impulses each superimposed on the other. If these impulses had not been timed so as to add to each other the oscillation would not have exceeded one-half a degree.

Repeated tests on battleships and submarines have demonstrated conclusively that roll and pitch do not cause the slightest deviation of the compass.

This information is, of course, of great value in considering the use of the compass in maneuvering ships in fleet or division formation, and proves conclusively that the most severe oscillations which can be introduced are hardly appreciable.

Up to the present time the adoption of the Sperry gyro-compass has proceeded without encountering that manifestation of the laws of inertia known as "conservatism." The author believes that, by reason of the results achieved, this will continue to be the case.

DISCUSSION.

Rear Admiral Bradley A. Fiske, U. S. N. (Communicated):—I have glanced over the paper of Mr. Gillmor called "The Sperry Gyro-Compass in Service." Mr. Sperry's gyroscope compasses are fitted in the Florida, and I am

very glad of the opportunity of testifying to their great efficiency for the purposes intended, and their value in naval work. Mr. Gillmor is very optimistic, but in my opinion he is not too optimistic.

Mr. Gillmor (Communicated):—This comment is especially valuable and interesting. As Commander of the First Division of the U. S. Atlantic Fleet, comprising the U. S. S. Florida, Flagship, and the U. S. S. Utah, Delaware and North Dakota, Rear Admiral Fiske has had an excellent opportunity to observe the operation of the Sperry gyro-compasses installed on these ships. His observation has extended not only to their use under ordinary conditions of navigation but also under the conditions of target practice and fleet maneuvers.

The Chairman:—We will proceed to the next paper on the program which is entitled "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, junior members of this Society.

The paper was presented by Mr. Hanson.

RUDDER TRIALS, U. S. S. STERETT.

By Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

1. This paper was first prepared as a thesis submitted to the Department of Naval Architecture of the Massachusetts Institute of Technology; and the writers desire to express their grateful appreciation to Prof. Cecil H. Peabody, under whose supervision, as head of that department, the tests were conducted, for many helpful suggestions, both in the preparations for the tests and in the analysis of results.

2. The objects of these trials were: (1) to determine the moment of pressure on the rudder in turning at various speeds and helm-angles; (2) to compare these values with the corresponding values given by Joessel's formula, and to obtain a coefficient of reduction thereon; (3) to establish a formula, directly applicable to this particular type of vessel; and (4) to investigate the condition of "meeting ship" with the helm when already turning, and the condition of turning with engines reversed.

3. It is believed that previous published turning trials have been conducted at speeds not greater than 20 knots, and that particular interest attaches to these trials on account of the high speeds (28 knots maximum) at which they were run.

4. The trials for the conditions of "meeting ship" and "backing" were made for the purpose of obtaining data which, it was hoped, would be of interest in the design of steering gear for ships of a type similar to that tested.

5. For these turning trials, the U. S. S. Sterett, a destroyer of recent design, was designated by the Navy Department. The trials consisted in securing, with a recording, spring dynamometer, a continuous record of tension in the standing part of one tiller chain, together with records of time, helm-angle, and revolutions of both turbines.

6. The results of the tests have been summarized in curves of twisting moment, both maximum and on steady turning, coefficients of reduction on Joessel's values, and an approximate empirical equation.

TABLE OF PRINCIPAL DIMENSIONS, ETC., U. S. S. STERETT, DESTROYER.

Built by Fore River Shipbuilding Co., Quincy, Mass., 1910.

Length between perpendiculars	289 ft. 0 in.
Length over all	293 ft. 10½ in.

Beam at load water-line	26 ft. $\frac{1}{2}$ in.
Beam extreme on guards	27 ft. 0 in.
Draught to normal load water-line	8 ft. 4 in.
Corresponding displacement	743.5 tons.
Wetted surface to load water-line	7,800 sq. ft.
Area of midship section to load water-line	144.96 sq. ft.
Area of load-water plane	5,030 sq. ft.
Tons per inch immersion at load water-line	11.9 tons.
Coefficient of fineness (block)	.4142
Coefficient of fineness (midship section)	.666
Coefficient of fineness, load water-line	.649
Estimated tactical diameter (preliminary acceptance trials)	650 to 675 yds.

Engines.

Type	72-inch, 14-stage Curtis marine turbines.
Number	Two (out turning).

Boilers.

Type	Yarrow water-tube.
Number	Four.
Total heating surface	18,000 sq. ft.

Propellers.

Type	True screw, solid.
Material	Monel metal.
Number	Two.
Diameter	6 ft. $6\frac{3}{4}$ in.
Mean pitch, starboard	75.69 in.
port	75.54 in.
Helicoidal area	21.06 sq. ft.
Projected area	18.21 sq. ft.

Performance on Standardization Trial, November 1, 1910.

Speed (average of high-speed runs)	31.633 knots.
Draught (middle of high-speed runs)	8 ft. $4\frac{7}{16}$ in.
Corresponding displacement ($4\frac{1}{2}$ in. trim by stern)	741 tons.
S. H. P. of main engines (average of high-speed runs)	14,515 calculated.

Performance on Rudder Trials, June 9, 1911.

Maximum speed	28.6 knots.
Draught (mean during trials)	9 ft. ½ in.
Corresponding displacement (trim 1 in. by head at beginning, 7 in. by stern at end)	835 tons.
Depth of water	12 to 20 fathoms.

The type of rudder with dimensions and necessary data for computation is given on Fig. 1, Plate 111. The general arrangement of steering gear, showing recording dynamometer, is given on Fig. 2, Plate 111.

RECORDING DYNAMOMETER.

A vertical spring dynamometer was inserted in the standing part of the port tiller chain. The deflection of the spring, which was a measure of the tension in the chain, was communicated by a suitable multiplying device to a fountain pen which traced on a moving strip of paper a continuous force curve. The dynamometer is indicated in Fig. 2, Plate 112, and shown in detail in Fig. 3, Plate 113, and in Plates 115, 116, and 117. A detailed description of dynamometer is given in Appendix I. The chronograph or recording device is shown in Fig. 4, Plate 114, and Plates 115, 116, and 117, and a description is given in Appendix II.

Before being installed on board ship, the dynamometer was calibrated by subjecting it to known tensile forces in a 150,000-lb. tensile testing machine. In Fig. 8, Plate 118, are shown calibration curves for five springs. The average deviation of the experimental points from the curves is less than 1.0 per cent of the maximum force applied. A detailed description of the method of calibration is given in Appendix III.

FRICTION TESTS.

Tests were made both in dry-dock and afloat to determine the friction of the steering gear. The ship was first placed in dry-dock, the mid-position of the rudder accurately established as described in Appendix IV, the special helm-angle indicator set up, and the dynamometer inserted in the port tiller chain (Fig. 2, Plate 112). The helm was repeatedly moved back and forth by power, and a continuous record obtained of the tension in the chain. The following day, similar tests were made with the ship moored alongside a pier. The analysis of the tests and the method of applying a correction for friction to the results of the turning trials subsequently made, are given in Appendix V.

METHOD OF CONDUCTING TURNING TRIALS.

On June 8 and 9, turning trials underway were carried out in Massachusetts Bay in the vicinity of Boston Light Ship. The trials made on the first day were not satisfactory owing to a stiff breeze and a rough sea. But on June 9 the conditions were so favorable that the whole program of tests previously outlined was completed in the one day.

The sea was smooth with a long ground swell. The mean displacement of the ship was 835 tons, 12.7 per cent greater than the displacement on standardization. The correction to the speed-revolution curve for this difference is discussed in detail in Appendix VI. The depth of water in which the trials were run varied from 12 to 20 fathoms.

A ship's telephone circuit was rigged from bridge to quarter-deck, and there was also on the bridge a push-button connected by solenoid to a tracing pen on the recording apparatus.

The procedure for a run was as follows. The ship was put upon a steady course at the desired speed (the corresponding revolutions per minute being maintained as nearly as possible except during actual turning, when the throttles were not touched). After steadying on course and speed for a reasonable length of time, a "stand by" was given to the engine-room and to the man in charge of the dynamometer and gear aft. The order was given to the helmsman "starboard 25°," etc., and simultaneously a "start turn" signal was given by bell to the engine-room, and a "jog" transmitted to the record roll (Plate 119). As the ship's head swung past 10°, 20°, and 30° by steering compass, one, two, and three notches were transmitted to the "signal" line on the record roll. Since a practically steady value of stress was in every case reached at 40° to 60° of swing, the turn was considered finished after swinging through eight points. The helm was then put amidships and the ship steadied on her course at the speed desired for the next turn. On each turn the time to put helm over was checked on a stop-watch, and the helmsman was coached to secure a uniform rate. The average rate at which the helm was put over was 3° per second.

For convenience the tests were begun at the lowest speed. The "meet ship" turns were run in wherever the speed of ship, and capacity of dynamometer spring already fitted, made it convenient. The full-power backing trials were made immediately after the turns at maximum speed ahead, and the trials were concluded with the backing turns at reduced power.

As a rough guide in the size of spring required at various speeds and helm-angles, Joessel's formula was used with a large coefficient of reduction for safety. After inserting the spring, the dynamometer was set up with

jigger and spring balance to an initial stress of 300 lbs., which was the basis of reference for the force curve through the trials.

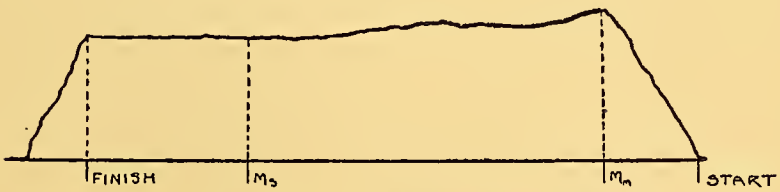
Three turns were made at each helm-angle; four different helm-angles were used at each speed, and there were five speeds ahead, in addition to "meet ship" turns (Table V) and full-power and reduced power backing turns. The total number of turns made was 74, and the total time required was seven hours.

The "meet ship" turns consisted in steadying on a course at prescribed speed, then putting the helm first port a certain number of degrees, then starboard. Continuous records were made and maximum and "steady" stress obtained for various conditions, such as "meeting" the ship, with starboard helm immediately after the helm had been put aport; and "meeting" her at various intervals of time after the ship's head had begun to swing to starboard.

Backing turns were made both at full power and at reduced power. These are described in detail in Appendix VII. The backing turns at full power are of particular interest because they give twisting moments more than 1.5 times as great as the maximum moments obtained on the turns at the highest speeds ahead.

ANALYSIS OF RECORDS.

FIGURE A



CURVE DRAWN BY RECORDING GEAR.

Figure A shows the force diagram obtained from the continuous record given on Fig. 9, Plate 119, with the scale of abscissæ reduced to one-quarter. The instant the helm starts to move, in beginning a turn, the force recorded on the dynamometer begins to rise and reaches a maximum at about the instant the helm reaches its maximum angle. During this time the ship first gives a slight kick to starboard (assuming helm put to starboard), then starts to turn to port. As she continues to turn, the tension in the tiller-chain falls off somewhat and then maintains a practically uniform or "steady" value after a swing of 40° to 50°. The ship then turns uniformly in her normal turning circle, and as there is practically no further variation in the

ordinate of the force curve the turn is considered finished after a swing of 90°. As soon as the helm is put back amidships, the tension in the tiller-chain falls rapidly to its initial value.

In Appendix VI is given a detailed description of the method employed in constructing a new speed-revolution curve for the displacement (12.7 per cent greater than on standardization) at which turning trials were run. From the record of port and starboard revolutions, together with the time record, the average revolutions per minute on approaching the turn were computed and the corresponding speed in knots obtained from the revised speed-revolution curve (Fig. 18, Plate 128). The rate of putting helm over was similarly obtained from the helm record line.

The tension in the tiller chain in pounds at any point during a turn is obtained from the corresponding ordinate of the force curve referred to the calibration plot for the particular spring used. Both the maximum tension and the tension on steady turning were measured and tabulated in Tables I, II, III, IV, appended.

As explained in Appendix V, the maximum forces recorded by the dynamometer were diminished by a certain amount to allow for the dynamic friction overcome in moving the rudder and gear. The forces recorded on steady turning, however, were not corrected for friction because it is believed that the static friction of rudder and gear was neutralized for this condition by vibration.

The forces recorded were reduced for average helm-angles of 16°, 26°, 31°, and 35°, these being the average values of the measured helm-angles which varied not more than 1° or 2° on either side of the averages.

CURVES OF TWISTING MOMENT.

From the data given in Tables I, II, III, and IV, curves were plotted with maximum twisting moments (*Mm*), and twisting moments on steady turning (*Ms*), as ordinates, on speed of approach in knots, as abscissæ. These curves were for the four average helm-angles referred to above, as shown on Figs. 10 and 11, Plate 120 and 121. On the curves of Fig. 10, Plate 120, it will be observed that there is a pronounced hump, beginning at about 22 knots speed $\left(\frac{V}{\sqrt{L}}=1.3\right)$. The average deviation of points from the curves is 1.5 per cent of the maximum value for *Mm* and 1.0 per cent of the maximum for *Ms*. Cross-curves of *Mm* and *Ms* on helm-angles as abscissæ were then plotted at constant speeds of approach, as shown on Figs. 12 and 13, Plates 122 and 123. From the following table, it appears that the ratio of *Mm* to *Ms* varies from 1.3 at 28 knots to 1.04 at 16 knots.

COEFFICIENT OF REDUCTION.

Table of $\frac{Mm}{Ms}$ (from faired curves, Figs. 10 and 12) (Helm-angle θ).

V (knots).	16°	26°	31°	35°
16.....	1.04	1.04	1.04	1.04
20.....	1.06	1.08	1.11	1.12
24.....	1.05	1.07	1.07	1.07
28.....	1.22	1.21	1.27	1.30

For purposes of comparison, the theoretical twisting moment by Joessel's formula was calculated at four helm-angles and a series of speeds. The rudder area was considered in three parts in the conventional way, and for each part, the center of pressure and twisting moment were computed. (See Fig. 1 for dimensions of rudder.)

θ = Rudder angle.
d = Distance of center of pressure from leading edge.
b = Width of part of rudder considered.
A = Area of part of rudder considered.
a = Distance of leading edge forward of axis.
V = Velocity of approach in feet per second.
M = Twisting moment in pounds-feet.

$$d = (.195 + .305 \sin \theta) b \qquad (1)$$

$$M = \left(\frac{.787 \sin\theta}{.195 + .305 \sin\theta}\right)(d - a) A V^2 \qquad (2)$$

The three values of M were added to obtain the total twisting moment at the rudder axis. The observed moment on steady turning was then compared with the calculated moment for a given speed and helm, and their ratio, the "coefficient of reduction" was plotted on velocity of approach (Fig. 14, Plate 124).

It appears that the coefficient of reduction is not a constant for this ship, but falls off at high speeds and large helm-angles. On Fig. 15, Plate 125, are plotted, on speed-length ratios $\left(\frac{V}{\sqrt{L}}\right)$ as abscissæ, the coefficients of

reduction published for the Condor and Cassini of the French Navy, together with the coefficients of reduction for the Sterett at 31° helm-angle. These ships are of somewhat similar type with principal dimensions as follows:—

	Sterett.	Condor.*	Cassini.†
	2 Screws, O. T.	2 Screws, O. T.	2 Screws, O. T.
Displacement, tons	835	1,272	960
V maximum, knots	29	20	20
Length, load water-line	289	223	262
Beam	26′ 0½″	29′ 2″	27′ 0″
Draught	8′ 4″	13′ 11″	10′ 3″
Rudder area (A), square feet	52.1	—	53.8
$\frac{A}{L \times D}$	.0218	—	.021
Fraction of compensation	.173	—	.215
Rate of moving helm, degrees per second	3	3	3

The coefficient of reduction for the Sterett was computed with reference to the twisting moment on steady turning, with no correction for friction (see Appendix V).

The coefficients of reduction for the Condor and Cassini are the maximum recorded moments corrected for friction, and divided by the moments obtained by Joessel's formula. The curves of coefficients of reduction for the three ships, plotted on Fig. 15, Plate 125, have the same general characteristics, and seem to show that for similar ships, at the same helm-angle and with the same speed-length ratio, the coefficient of reduction is practically constant. But, for the same ship, the coefficient of reduction is not constant for different speeds or helm-angles.

PROPOSED FORMULA FOR TWISTING MOMENT.

From the curves of twisting moment on steady turning plotted on speed of approach (Fig. 10, Plate 120) and on degrees of helm-angle (Fig. 12, Plate 122), it appears that the twisting moment varies neither as the square of the speed, nor as the sine of the helm-angle, as proposed by Joessel, but rather with some other function of these two quantities.

*Pollard et Dudebout, Theorie du Navire, Tome IV, p. 36.

†M. Laubeuf, Bulletin de l'Association Maritime, 1897, p. 215.

The curves of twisting moment on speed may be expressed by an equation of the form $M=KV^n$, where n varies with the speed-length ratio, causing the hump in the curves (Fig. 10, Plate 120). The average value of n for all the curves on steady turning (Fig. 10, Plate 120) was found to be 1.75.

The curves of twisting moment plotted on helm-angles are, for angles above 15°, straight lines which when produced do not all pass through the origin. The equation for any line is therefore of the form, $M=K(\theta-\delta)$, in which δ is the value of the intercept on the axis of abscissæ. For speeds above 20 knots, the average value of δ is 4°. It seems not unlikely that the helm-angle (θ) should be diminished by some small angle which may be a function of the drift angle. One of the conclusions drawn from Wellenkamp's rudder trials* for the German Navy, reported by T. Schwartz, is that the rudder angle is diminished by the angle of drift in turning.

The equation for twisting moment may then be expressed in the form:—

$$M=KV^{1.75}\ (\theta-\delta)$$

or in terms of the rudder constants,

$$M=K'AX_0V^{1.75}\ (\theta-4^\circ)$$

in which A is the rudder area in square feet, and X_0 is the distance in feet from the center of area of the rudder to the rudder axis. The value of K' in this equation was computed, from the curves of Fig. 10, Plate 120, to be 0.06, or—

$$M=0.06AX_0V^{1.75}(\theta-4^\circ).$$

With this formula, points were computed for new curves of twisting moment on speeds between 12 and 28 knots. The resulting curves are shown by broken line on Fig. 10, Plate 120. The greatest deviation of these new curves from the original curves of twisting moment on steady turning is less than 10 per cent, and the average deviation is less than 2 per cent of the moment at 35° and 28 knots.

The formula presented above is a simple mathematical form for the results of the tests. It applies to the particular ship and rudder tested, but cannot safely be assumed to apply, with the same constants, to ships of very different form. However, the curves (Fig. 15, Plate 125) of coefficient of reduction on Joessel's formula plotted on speed-length ratio $\frac{V}{\sqrt{L}}$ seem to show that ships of nearly the same type behave similarly in turning, and that whatever formula is used in computing the twisting moment, the same constants may be applied to ships of similar type.

*See "Jahrbuch der Schiffbautechnischen Gesellschaft, 1910" "Uber Rudermomentmessungen," T. Schwartz, p. 714: "Die Derivationswinkel gestaltet den wirksamen Ruderwinkel kleiner, da die auf die Ruderfläche wirkenden Stromfäden in der Richtung der Kurve der Heckbahn verlaufen."

"MEET SHIP" TURNS.

On these turns, the results of which are tabulated in Table V, the helm was first put over to port, and then, after a definite interval of time, to starboard. The maximum tension recorded by the dynamometer occurred in all cases just after the helm had been started from port to starboard, *i. e.*, practically at the instant of "meeting ship." A correction for friction was applied, corresponding in each case to the maximum recorded starboard helm. The twisting moment was computed from the resulting maximum stresses, and compared with the maximum twisting moments obtained by interpolation from the curves of Fig. 11, Plate 121, for the same speeds and helm-angles on the regular turns. The moment developed on "meeting ship" appears to be, on an average, about 12 per cent greater than on normal turning.

The interval of time during which the ship was allowed to swing under port helm, before "meeting" her, varied from $3\frac{1}{4}$ seconds to 45 seconds apparently with no considerable difference in the effect on the twisting moment developed.

The record of revolutions per minute showed that on the initial swing to starboard (*i. e.*, with port helm), the revolutions per minute of the inboard screw were about 10.8 per cent less than those of the outboard screw, and that on the subsequent turn to port after "meeting ship," they were about 8.4 per cent less.

BACKING TURNS.

Two turns were made with engines backing at full power and two with engines backing at reduced power. On the first full-power turn, the ship being dead in the water, the engines were reversed and the helm simultaneously put over to 32° port, before the ship had gathered sternway. The force curve obtained was similar in shape to those for turns ahead; but the maximum tension recorded, 13,600 lbs., corresponding to a twisting moment of 145,000 lbs.-feet at the rudder head, was 1.53 times as great as the maximum tension recorded on the previous turns, corrected for friction.

On the second full-power backing turn, the engines were first reversed and the ship allowed to acquire considerable sternway before putting the helm aport (32° maximum). On this turn the maximum tension recorded was 13,980 lbs., corresponding to a twisting moment of 149,100 lbs.-feet at the rudder head. This is nearly 1.58 times the maximum tension on the turns at highest speed ahead. In both of the full-power turns, the vibration was very violent, and no correction for friction has been applied to the tensions developed in these turns.

A detailed description of the backing turns is given in Appendix VII.

EFFECT OF WAVES.

The turning trials on June 8 were run in a choppy sea with breaking waves of height about four feet. The wind was estimated at "four" of Beaufort's scale.

Turns were made at speeds from 15 to 23 knots. When turning at 23 knots, water came over the deck in such quantities that the electrical leads from the recording gear were short-circuited. The trials were therefore discontinued.

The results obtained this day were irregular and chiefly of interest when compared with the data from smooth-water turns. The maximum recorded moment on any turn was 35 per cent greater than the maximum moment recorded the following day for the same speed and helm. The effect of waves was to cause the force curve to fluctuate by a total amount equal to 40 per cent of the average ordinate. The average moment on steady turning was 15 per cent greater than the corresponding moment in smooth water.

CONCLUSIONS.

The material presented above seems to warrant the following conclusions:—

1. A given coefficient of reduction for Joessel's formula may be applied to similar ships, with rudders of the same type, only for the same helm-angle and at corresponding speeds, *i. e.*, $\frac{V}{\sqrt{L}}$ = constant.

2. In turning with the helm alone, the maximum tension in the rudder chain (including friction of gear) occurs at the instant the helm has reached its extreme position, and amounts to 139 per cent of the tension when the ship is turning uniformly, at 28 knots and 35° helm.

3. The maximum twisting moment on the rudder post occurs at the same instant as (2) above, and amounts to 130 per cent of the moment when ship is turning uniformly at 28 knots and 35° helm.

4. The rudder moment to "meet ship," when turning amounts to about 112 per cent of the moment, exerted in steady turning with same speed and helm.

5. The effect of waves of height about four feet is to produce a maximum moment, when turning, of 135 per cent of the maximum moment when turning in quiet water.

6. The force exerted by the steering engine to overcome the friction of the leads to the rudder yoke is 24 per cent of the maximum force exerted

on turning, at 28 knots and 35° helm, in quiet water. This seems to be a disadvantage of a location of the steering engine forward in a ship of such length.

7. The greatest moment measured during these trials was obtained in backing full power with full helm. The rudder moment for this condition amounted to 1.6 times the moment recorded on steady turning at 28 knots and 35° helm.

With the results of these rudder trials at hand, it would be of interest to determine, with precision, the path of the Sterett in turning with a view to establishing the relation between the rudder moment and the maneuvering qualities of this type of ship.

To afford data for the design of steering gear and rudder posts, using a definite factor of safety, such rudder trials as are here described should be conducted in rough weather.

TABLE I.—TURNS AT 16° HELM.

Turn.	R. P. M.	Velocity of approach, knots.	Angular velocity of helm, degrees per second.	Observed helm-angle.	To reduce to mean helm-angle 16°.	Correction for dynamic friction.	Total correction.	Maximum tension recorded on dynamometer.	Corrected maximum tension.	Maximum twisting moment at rudder post.	Recorded tension on steady turning.	Reduced to 16° helm-angle.	Twisting moment on steady turning.
										Mm.			*Ms.*
A	584	28.0	2.94	16	—	−900	− 900	4,450	3,550	37,865	2,800	2,800	29,865
B	583	27.9	2.57	14	+448	−870	− 422	4,000	3,578	38,165	2,600	3,070	32,740
C	582	27.9	2.44	16	—	−900	− 900	4,660	3,760	40,100	2,650	2,650	28,260
A	518.5	25.7	3.45	15	+190	−880	− 690	3,500	2,810	29,970	2,580	2,780	29,650
B	543	26.5	2.44	15	+200	−880	− 680	3,540	2,860	30,500	2,500	2,710	28,905
C	538	26.4	2.86	15	+200	−880	− 680	3,540	2,860	30,500	2,460	2,670	28,475
A	454	23.3	3.17	16.5	− 80	−900	− 980	3,280	2,300	24,530	2,080	2,003	21,360
B	443	22.9	3.34	15	+150	−880	− 730	2,810	2,080	22,180	2,100	2,250	24,000
C	454	23.3	3.51	15	+155	−880	− 725	3,240	2,515	26,820	2,020	2,175	23,195
A	388	20.4	—	17	−126	−910	−1,036	3,040	2,004	21,370	1,800	1,690	18,025
B	369.5	19.5	2.99	16.5	− 58	−905	− 963	2,980	2,017	21,510	1,820	1,770	18,880
C	383.5	20.1	1.93	14.5	+180	−875	− 695	2,600	1,905	20,320	1,560	1,720	18,345
A	301	16.2	3.57	16	—	−900	− 900	2,220	1,320	14,080	1,420	1,420	15,145
B	308	16.5	3.45	16	—	−900	− 900	2,260	1,360	14,505	1,300	1,300	13,865
C	298	16	3.70	16.5	− 40	−905	− 945	2,260	1,315	14,025	1,340	1,318	14,055

TABLE II.—TURNS AT 26° HELM.

Turn.	R. P. M.	Velocity of approach, knots.	Angular velocity of helm, degrees per second.	Observed helm-angle.	To reduce to mean helm-angle 26°.	Correction for dynamic friction.	Total correction.	Maximum tension recorded on dynamometer.	Corrected maximum tension.	Maximum twisting moment at rudder post.	Recorded tension on steady turning.	Reduced to 26° helm-angle.	Twisting moment on steady turning.
										Mm.			*Ms.*
A	569	27.5	3.22	27	−240	−1,050	−1,290	7,600	6,310	67,290	5,420	5,170	55,140
B	559.5	27.1	2.86	26	—	−1,050	−1,050	6,940	5,890	62,830	5,150	5,150	54,925
C	581.5	27.9	3.33	26	—	−1,050	−1,050	7,340	6,290	67,080	5,120	5,120	54,605
A	524	25.9	2.86	25	+220	−1,030	− 810	6,160	5,350	57,060	4,700	4,925	52,530
B	522.5	25.8	2.86	25	+220	−1,030	− 810	6,065	5,255	56,040	4,660	4,885	52,100
C	543	26.5	2.86	25	+230	−1,030	− 800	6,260	5,460	58,230	4,680	4,915	52,420
A	441.5	22.6	3.14	26	—	−1,050	−1,050	4,940	3,890	41,490	3,680	3,680	39,250
B	451.0	23.2	3.17	25	+180	−1,035	− 855	4,940	4,085	43,570	3,900	4,075	43,465
C	420.9	22.0	3.23	25	+162	−1,035	− 873	4,660	3,787	40,390	3,460	3,610	38,500
A	376	19.8	3.38	24.5	+216	−1,030	− 814	4,020	3,186	33,980	2,740	2,920	31,140
B	380	20	3.26	24.5	+218	−1,030	− 812	3,840	3,028	32,290	2,700	2,895	30,875
C	386	20.3	2.86	26.5	− 75	−1,060	−1,135	4,260	3,125	33,330	2,940	2,872	30,630
A	291	15.6	—	25	+ 93	−1,035	− 942	2,940	1,998	21,310	2,000	2,075	22,130
B	301	16.1	—	27.5	−160	−1,070	−1,230	3,840	2,610	27,835	2,020	1,915	20,420
C	299	16.1	—	26.5	− 52	−1,060	−1,112	3,350	2,238	23,870	2,000	1,968	20,990

TABLE III.—TURNS AT 31° HELM.

Turn.	R. P. M.	Velocity of approach, knots.	Angular velocity of helm, degrees per second.	Observed helm-angle.	To reduce to mean helm-angle 31°.	Correction for dynamic friction.	Total correction.	Maximum tension recorded on dynamometer.	Corrected maximum tension.	Maximum twisting moment at rudder post.	Recorded tension on steady turning.	Reduced to 31° helm-angle.	Twisting moment on steady turning.
										Mm.			*Ms.*
A	559	27.1	2.94	29.0	+480	−1,120	− 540	7,730	7,090	75,600	6,040	6,165	65,760
B	581	27.9	2.71	30.5	+138	−1,120	− 980	8,400	7,420	79,100	6,240	6,370	67,940
C	581.5	27.9	2.94	30.0	+264	−1,120	− 856	8,200	7,344	78,330	6,150	6,280	66,980
A	526	25.9	3.23	31.0	—	−1,110	−1,110	8,280	7,170	76,460	5,640	5,765	61,485
B	532	26.2	3.03	30	+240	−1,110	− 870	7,900	7,030	73,000	5,920	6,159	65,600
C	529	26.1	3.03	31	—	−1,130	−1,130	8,900	7,770	82,920	6,100	6,100	65,060
A	445.5	23.0	2.90	30	+169	−1,110	− 940	6,240	5,300	56,525	4,700	4,870	51,940
B	445	22.9	3.17	30	+106	−1,110	− 944	6,000	5,066	53,920	4,440	4,610	49,165
C	450	23.1	3.03	31	—	−1,130	−1,130	6,540	5,410	57,700	4,750	4,750	50,660
A	380	20.0	3.23	31.5	− 62	−1,135	−1,197	5,000	3,803	40,560	3,590	3,525	37,600
B	378.5	19.9	3.45	30.5	+ 60	−1,120	−1,060	4,690	3,630	38,715	3,280	3,342	35,645
C	386.5	20.3	3.29	31	—	−1,130	−1,130	5,060	3,930	41,920	3,340	3,340	35,625
A	294.5	15.7	3.45	32	− 75	−1,130	−1,205	3,840	2,635	28,100	2,840	2,320	24,740
B	278	15.1	3.71	31.5	+ 33	−1,135	−1,168	3,900	2,732	29,140	2,400	2,375	25,330
C	284.5	15.4	3.33	31	—	−1,130	−1,130	3,940	2,810	29,970	2,400	2,400	25,600

TABLE IV.—TURNS AT 35° HELM.

Turn.	R. P. M.	Velocity of approach, knots.	Angular velocity of helm, degrees per second.	Observed helm-angle.	To reduce to mean helm-angle 35°.	Correction for dynamic friction.	Total correction.	Maximum tension recorded on dynamometer.	Corrected maximum tension.	Maximum twisting moment at rudder post.	Recorded tension on steady turning.	Reduced to 35° helm-angle.	Twisting moment on steady turning.
										Mm.			*Ms.*
A	575	27.7	3.03	33	+470	−1,190	− 720	9,380	8,660	92,340	7,340	7,340	78,310
B	554.5	26.9	2.71	32	+705	−1,170	− 465	9,160	8,695	92,700	7,040	7,285	77,705
C	556.5	27	2.57	33	+470	−1,180	− 710	9,560	8,850	94,400	7,100	7,225	77,040
A	533	26.2	3.13	34	+210	−1,170	− 960	9,540	8,590	91,550	6,700	6,923	73,850
B	523	25.9	3.08	35	—	−1,190	−1,190	9,640	8,450	90,165	6,900	6,900	73,600
C	535	26.3	2.94	35	—	−1,190	−1,190	9,660	8,470	90,380	6,800	6,800	72,540
A	436	22.6	2.78	35	—	−1,190	−1,190	—	—	—	5,100	5,265	56,150
B	445	23.0	2.64	35	—	−1,190	−1,190	7,000	5,810	61,960	5,520	5,520	58,870
C	439.5	22.8	2.78	35	—	−1,190	−1,190	7,000	5,810	61,960	5,500	5,500	58,655
A	384.5	20.2	2.90	34	+ 92	−1,170	−1,078	5,500	4,422	47,160	4,150	4,285	45,700
B	390.5	20.7	—	34	+ 95	−1,170	−1,075	5,660	4,585	48,900	3,900	4,038	43,070
C	382.5	20.1	—	34	+ 91	−1,170	−1,079	5,600	4,521	48,215	3,900	4,035	43,035
D	388.5	20.5	2.82	34	+ 90	−1,170	−1,080	5,680	4,600	49,060	4,100	4,236	45,180
A	277	15.0	3.33	36	− 32	−1,200	−1,168	3,840	2,672	28,500	2,680	2,630	28,050
B	297.5	16	3.23	34	+ 41	−1,170	−1,130	3,650	—	—	2,820	2,885	30,770
C	287.5	15.5	3.45	36	− 37	−1,200	−1,163	3,940	2,777	29,620	2,820	2,880	30,715

TABLE V.—RESULT OF "MEETING SHIP" TURNS.

Speed of approach.		Helm-angle (maximum).		Rate of putting helm over.* Degrees, per second.		Time between helm aport and instant started to starboard seconds.	Maximum tension recorded on dynamic pounds.	Correction for friction.	Corrected maximum tension.	Maximum twisting moment $M'm$.	Maximum twisting moment from curves, plate Mm.	Ratio $\frac{M'm}{Mm}$	R. P. M. head swinging to starboard.		†Per cent difference $\frac{P-S}{P}$.	R. P. M. head swinging to port.		‡Per cent difference $\frac{S-P}{S}$.
Knots.	R. P. M.	Port.	Stbd.	To port.	To stbd.								Port.	Stbd.		Port.	Stbd.	
19.5	370	23.5	26.5	2.86	3.57	38¼	4,040	1,180	2,860	30,500	32,000	0.95	386	352	8.8	348	382	8.9
—	—	23.5	24.5	3.23	3.57	45¼	4,440	—	—	—	—	—	394	342	13.2	—	—	—
—	—	23.0	26.0	2.50	3.57	40¾	4,360	—	—	—	—	—	396	354	10.6	—	—	—
20.7	393.5	23.0	24.0	3.03	3.23	3¼	4,500	1,020	3,480	37,100	32,500	1.15	—	—	—	360	388	7.4
19.4	367	32.5	34.5	2.86	3.57	30¾	5,680	1,180	4,500	48,000	44,000	1.11	348	300	13.8	302	348	13.2
17.5	328	32.5	34.5	3.45	3.13	25	5,780	1,180	4,600	49,000	36,500	1.35	—	—	—	325	349	6.9
18.7	352	33.0	34.5	—	4.00	22⅜	6,160	1,180	4,980	53,100	41,500	1.28	376	336	10.6	—	—	—
26.3	535	22.0	24.5	—	3.57	33¾	7,020	1,020	6,000	64,000	54,000	1.19	536	516	3.7	—	—	—
25.8	521	24.0	23.5	—	3.45	38½	6,960	1,010	5,950	63,400	52,500	1.21	524	486	7.2	485	528	8.1
26.7	547	23.0	24.5	2.39	3.57	38⅛	7,160	1,020	6,140	65,400	59,000	1.11	532	496	6.7	500	536	6.7
27.5	570	31.0	34.5	2.56	3.33	10½	9,900	1,180	8,720	93,000	97,500	0.95	—	—	—	—	—	—
27.5	570	31.0	34.5	2.56	3.23	29	9,700	1,180	8,520	90,800	97,500	0.93	586	526	10.2	510	566	9.9
28.6	602	32.0	34.5	—	3.45	27	9,540	—	8,360	—	—	—	602	544	9.6	548	586	6.5

*Mean rate of putting helm over to port 2.83° per sec.
to starboard 3.48° per sec.

†Mean $\frac{P-S}{P}$ 10.8 per cent (turning to starboard).

‡Mean $\frac{S-P}{S}$ 8.4 per cent (turning to port).

APPENDIX I.

DESCRIPTION OF SPRING DYNAMOMETER.

A spring dynamometer was designed to measure the tension in the standing part of the port tiller chain. In order to economize on the very restricted deck space, a vertical "shear-legs" type was chosen, with a reducing motion of one to five. The shear-legs *B* and *C* (Fig. B, Plate 113) are of 1-inch steel plate doubled, connected by tie *T*, through pins *M* and *N*. At the lower end, the legs *B* and *C* are secured by pins *G* and *H* to the chain grips *E* and *F*. The latter consist each of a pair of 1-inch steel plates slotted out to take two links of $\frac{7}{8}$-inch chain. These plates are drawn together by bolts to grip the chain securely. Before setting up, at least two inches of slack chain is provided between them. This is ample, because the motion of the chain grip, *F*, is only $\frac{3}{10}$-inch maximum. The tension in the chain is transmitted from the chain grips through the shear-legs to the spring *S*. The chain grips, as well as the lower ends of the shear-legs, rest on a slushed iron plate.

The grip *E* is secured to the inboard, standing end of the chain, the hand steering gear being locked. The leg *B* of the dynamometer thus becomes the standing leg, and force is measured by the deflection of the leg *C* as the spring *S* is compressed.

The two legs of the dynamometer project vertically through a slot cut in the top of the heavy oak table, shown in Figs. B, 5, 6, and 7, Plates 113, 115, 116, and 117. The standing leg *B* is securely blocked to the table. The leg *C* is free to move in the direction of the slot.

Springs of such strength were chosen that the motion of *P* should be less than half an inch. A limit stop is fitted in the slot to bear against *C*, and protect the recording gear in case the motion of *P* is as great as $\frac{3}{4}$ inch.

The motion of *P* is transmitted to the recording gear by a fourfold multiplying purchase consisting of a monel metal wire diameter 0.009, led over two double $\frac{3}{4}$-inch indicator pulleys to the carriage on the recording gear. The latter is mounted on a corner of the table top. The motion of $\frac{3}{4}$-inch compression in spring is transmitted as a motion of 3 inches of the recording carriage.

APPENDIX II.

RECORDING GEAR.

The recording gear mentioned above is practically a reproduction of the instrument used on the Froude by the Department of Naval Architecture, Massachusetts Institute of Technology. A description in detail by Prof. H. A. Everett was published in the 1911 Proceedings of the Society of Naval Architects and Marine Engineers. The essential features are:—

1. A 0.1 horse-power shunt motor, operating on 110 volts, direct current; to turn the roll of paper for a continuous record.

2. A fountain pen to trace a reference or base line for the curve of tension in the chain.

3. A pen to trace a curve of tension in the chain. The carriage for this pen is connected to the free leg of the dynamometer by a fourfold purchase as described in Appendix 1.

4. Pens to record revolutions of port and starboard propellers. These pens are connected through solenoids to mechanical counters operated by cams on the ship's revolution counter shafts. At each revolution of these shafts, corresponding to ten revolutions of the main turbine shafts, the solenoid circuit is temporarily closed, making a jog on the record of revolutions, from which, with the accompanying time record, the revolutions per minute for each turbine can be determined.

5. A pen to indicate the motion of the helm. This pen is actuated by a solenoid connected to the special helm-angle indicator described in Appendix 4, Fig. 16, Plate 126. From this record helm-angles and rate of putting over helm can be read.

6. A pen actuated by a solenoid from a push-button on the bridge, for prearranged signals such as "Stand by," "Beginning of turn," "Ship's head turned 10°, 20°, 30°, or 90°, etc."

7. A pen to mark quarter-seconds of time. This pen is actuated by solenoid by means of a special Chelsea clock which closes the circuit at half-second intervals.

8. The recording gear is mounted on a mahogany board bolted to the oak table of the dynamometer by carriage bolts. Rubber washers one inch thick were placed between the recording gear and table top to take up vibration.

9. A battery box of twelve dry cells, "Navy Type," with two cells in series on each solenoid circuit giving 4 to 5 volts.

The recording gear including clock, motor, pens, solenoids, revolution counters, and helm indicator gave complete satisfaction in its operation.

The general arrangement of pens, solenoids, paper rolls, etc., is shown on Fig. 4, Plate 114; and a specimen record made when turning is shown on Fig. 9, Plate 119.

APPENDIX III.

CALIBRATION OF DYNAMOMETER SPRINGS.

TABLE OF SPRINGS TESTED.

Spring No.	Free length.	Mandrel.	Wire.	Load* for $\frac{1}{2}''$ compression.	Maximum load applied on calibration.
X.....	6″	$1\frac{3}{4}''$	$\frac{3}{8}''$ sq.	1,600 lbs.	1,600 lbs.
60.....	6″	$1\frac{3}{4}''$	$\frac{7}{16}''$ sq.	2,500 lbs.	3,000 lbs.
62.....	6″	$1\frac{3}{4}''$	$\frac{9}{16}''$ sq.	6,400 lbs.	8,200 lbs.
63.....	6″	$1\frac{3}{4}''$	$\frac{5}{8}''$ sq.	10,100 lbs.	12,400 lbs.
67.....	6″	$1\frac{3}{4}''$	$\frac{11}{16}''$ sq.	14,800 lbs.	15,600 lbs.

The springs used in the dynamometer were steel safety-valve springs purchased from the Crosby Steam Gage and Valve Company of Boston. The considerations which governed the choice of springs were:—

1. The maximum capacity, roughly estimated in advance by applying Joessel's formula.

2. The maximum ordinate for the force diagrams, for which $1\frac{3}{4}$ inches to 2 inches was fixed upon as a reasonable height; this corresponds to a compression of the spring equal to one-fourth the ordinate (about $\frac{1}{2}$ inch), owing to the fourfold purchase which was used to transmit the motion of the dynamometer to the stress-recording pen.

3. A permissible compression of one inch in the spring before closing.

To prevent the possibility of exceeding the capacity of the springs, a limit stop was secured to the dynamometer table, which restricted the compression of the springs to $\frac{3}{4}$ inch.

The dynamometer and springs were calibrated on the 150,000-lb. rope-testing machine in the Mechanical Engineering Laboratory of the Massachusetts Institute of Technology. A wooden platform, covered with a $\frac{3}{4}$-inch greased steel plate, was built up on the ways of the testing machine between the straining heads. The dynamometer and supporting table rested on this platform and at such a height that the pull exerted by the straining heads should act along the axis of the dynamometer chain grips. A length

*This corresponds to an ordinate of 2 inches on force diagram.

of $\frac{7}{8}$-inch chain was secured in the dynamometer with 3 or 4 inches of slack between the grips. The free ends were shackled to the straining heads of the testing machine. The recording gear was rigged exactly as it was to be used on the actual turning trials.

The procedure during calibration was as follows:—After setting up a spring in the dynamometer, and throwing a load on and off several times to loosen up the gear, the beam of the testing machine was set at 300 lbs.

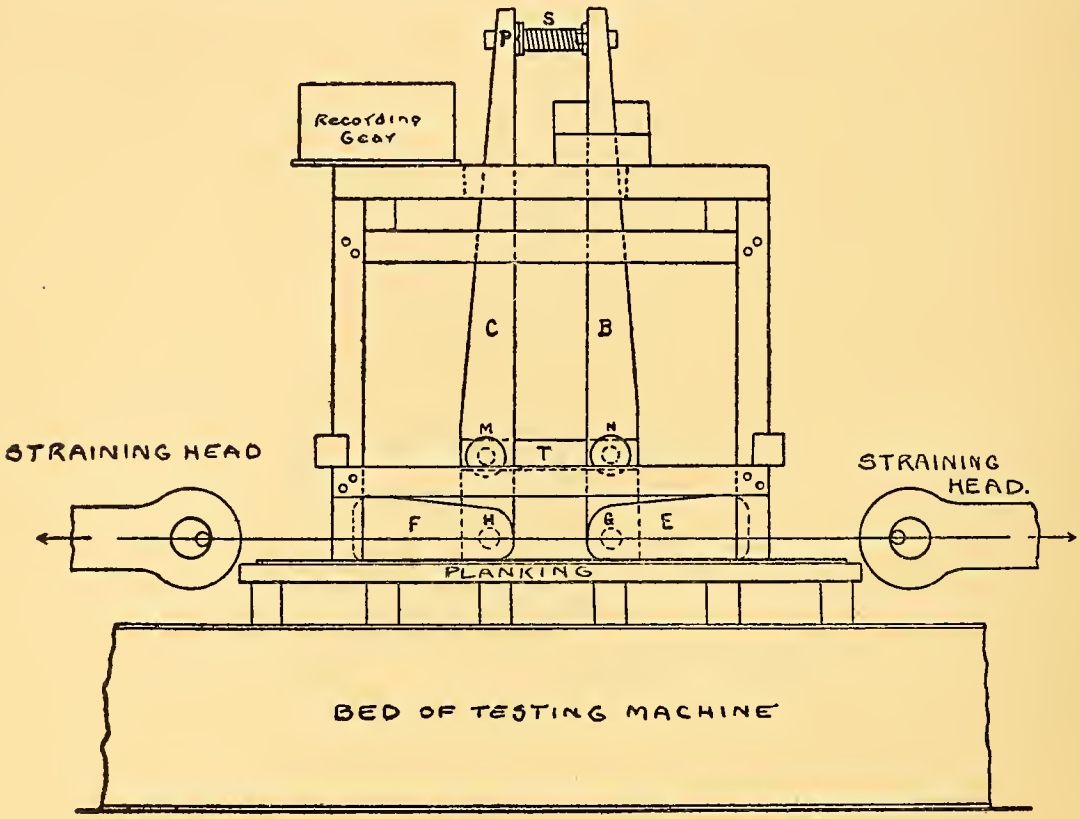


FIGURE B

The paper-record roll was then started and the load brought up until an exact balance was obtained on the testing machine. The base-line pen was then set to coincide with the tracing of the force-recording pen in this condition. This insured a constant, definite reference line which was maintained for all succeeding tests for this spring. The load was then increased by steps of 200 lbs. (500 lbs. for springs Nos. 62, 63, and 67) at a uniform rate of the straining-head of .025 foot per minute (.052 foot per minute for the three heavier springs) to the maximum loads shown in the foregoing

table. The load was then reduced by steps to 300 lbs., when the force-diagram pen again coincided with the fixed base-line. Throughout the calibration, both the base-plate and table were rapped and jarred continuously to remove any binding effect of friction on base-plate or in pins. The straining head was stopped at each successive load, both increasing and decreasing, long enough to get a good force-diagram at constant load, from which to measure the ordinates for the calibration curves shown on Fig. 8, Plate 118.

These curves all show a deflection of zero at 300 lbs. load, the abscissæ being pounds load, while the ordinates are linear units (centimeters for the particular cross-section paper used), and were taken directly from the continuous force-diagrams obtained on calibration. The calibration curves were subsequently used to pick out the maximum and steady values from the force-diagrams obtained both on the turning trials and on the friction tests. Care was taken in all cases to pick out increasing and decreasing stresses on the proper curves, the latter lying uniformly above the former.

The average deviation of the points from the calibration curves is about .05 cm., which amounts to an error of less than one per cent of the maximum ordinate. The precision of reading the scale of the testing machine is less than one-quarter per cent.

APPENDIX IV.

DESCRIPTION OF HELM-ANGLE INDICATOR AND DETERMINATION OF CENTER LINE OF SHIP.

The continuous record of helm-angles, both on friction tests and tests under way, was obtained by means of a tracing pen and solenoid on the recording gear, electrically connected to the special indicator shown on Fig. 16, Plate 126. This indicator was fitted as follows. A 1-inch mahogany board, cut to proper shape, was set up against the rudder head and bolted securely to the deck. Into this board was fitted a strip of ebonite $\frac{1}{2}$ inch thick and of $6\frac{1}{2}$ inches radial width, sawed to a circular arc of $16\frac{1}{2}$ inches (outer radius) concentric with the rudder stock. Into the ebonite arc, at carefully graduated intervals of 1°, were inserted radial strips of brass $\frac{1}{32}$ inch thick, projecting slightly above the surface of the ebonite. A copper wire ran from a binding post through a slot on the under side of the ebonite arc and was soldered to each of the brass strips. A pointer cut out of $\frac{1}{8}$-inch sheet brass was secured by tap-screws to the rudder head, in such a position as to sweep over the strip of ebonite when the helm was put over from one extreme position to the other. A wire was then run from the binding post of the ebonite strip to the battery box, and another wire from a screw contact on the moving pointer to the solenoid on the chronograph, and thence to battery. As the helm was put over in either direction, the brass pointer swept across the surface of the ebonite arc, alternately making and breaking circuit and giving a continuous record of degrees, except on 0° and on 5°, 15°, and 25°, on which points the brass contact strips had been omitted to facilitate distinguishing these intervals on the record.

In general this device was very satisfactory. But on the backing tests and on several other occasions water splashed up on deck, causing a continuous closed circuit over several degrees of helm. It was not difficult, however, on analyzing the records, even in such cases, to determine the helm-angle. On most of the turns, an observer was stationed at the indicator to check the recorded helm-angles.

For the proper location of the 0° point of the helm-angle indicator, the true fore-and-aft center-line of the ship was established in dry-dock as follows. The half-breadth of the keel was carefully measured and center-punched at a point about 25 feet forward of the stern-post. Then on the

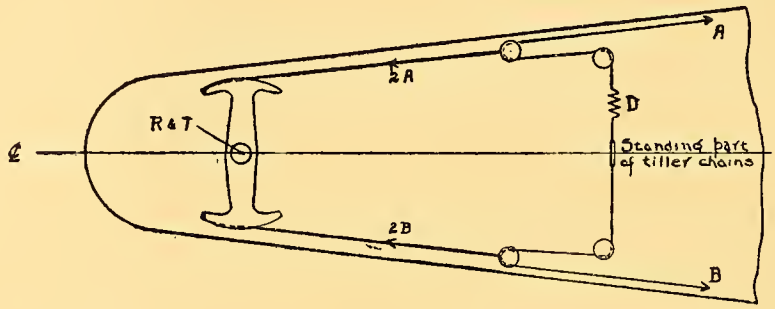
rise of the keel, just forward of the rudder, the half-breadth was again measured and center-punched at two points, and a straight-edge through these two points carried down to the top of the keel-blocks. This gave a second point on the center-line, which was then snapped in over the tops of the keel-blocks with a chalk line. As a check the half-breadth of keel was measured and projected down to the keel-blocks at still another point. The after edge of the rudder was then set by straight-edge on the true center-line, and the stationary part of the helm indicator set and bolted in position with its 0° point directly under the pointer on the rudder head.

APPENDIX V.

ANALYSIS OF FRICTION TESTS.

On June 6, 1911, the Sterett was placed in dry-dock, and water pumped out of the dock. The dynamometer described in Appendix I, Fig. B, Plate 113, was inserted in the standing part of the port-tiller chain as indicated by letter *D*, Fig. C. The steering wheel aft was locked, and power applied from the steering engine forward to move the rudder. The helm was repeatedly moved from 35° port to 35° starboard and back by means of the steering engine. The dynamometer gave a continuous record of the tension in lead *A*. Care was taken to move the helm at a constant rate (about 2° per second), and the dynamometer table was rapped continuously to take out

FIGURE C.



any friction in the dynamometer. The conditions of the calibration tests (Appendix 3) were further simulated by putting a greased plate between the deck and the foot of the dynamometer. On June 8 the friction tests were repeated with the ship afloat and moored alongside a pier.

On the curves for friction (Fig. 17, Plate 127) the dynamometer readings in pounds are plotted as ordinates on degrees helm-angle as abscissæ. Since the forces recorded in moving the helm from "hard over" to amidships did not differ materially from those recorded on continuing the motion from amidships to the other hard-over position, the friction curves represent only one-half the total arc of helm motion.

In the discussion of the friction tests, the following notation is used, the various forces being in pounds:—

D = Dynamometer reading, giving tension in lead *A*.
A = Force to overhaul lead *A* (port side).

B = Force to overhaul lead B (starboard side) A and B are assumed to be equal.

R = Force required at end of tiller yoke to overcome rudder friction.

T = Force required at end of tiller yoke to overcome moment of water-pressure against rudder, when under way.

W = Force required at end of tiller yoke to overcome moment of water-pressure against rudder, when moored alongside pier.

NOTE.—Owing to the double purchase in A and B, a force in either lead, forward of the sheaves, is equivalent to a force twice as great, at the end of the tiller yoke.

The cases considered are:—(1) Helm moving to starboard. The force in dynamometer (D) equals force required to overcome the friction of overhauling lead B plus one-half force to overcome friction of rudder in its bearings, *i. e.:*

$$D_1 = B + \tfrac{1}{2}R \text{ (curves I and V, Fig. 17)} \qquad (1)$$

2. Helm moving to port. The force in dynamometer D_2 equals force to overcome friction of overhauling lead A, *i. e.*,

$$D_2 = A = B \text{ (curves II and IV, Fig. 17)} \qquad (2)$$

$$\therefore D_1 - D_2 = B + \tfrac{1}{2}R - B = \tfrac{1}{2}R \text{ (curve III, Fig. 17)} \qquad (3)$$

On the tests afloat, the value of D_1 was found to be not greatly different from, although somewhat less, than that obtained in dry-dock. The value of D_2 afloat, however, was found to be considerably greater than in dry-dock. There are several factors which may serve to explain this increase in D_2 with the consequent decrease in $D_1 - D_2 = \frac{1}{2}R$.

1. The tests in dry-dock were made in a heavy rain, with decks, chains, fair leads, etc., wet. Therefore we might naturally expect the friction of deck-leads to be less than on the second day, when the deck was dry and gear probably somewhat rusted.

2. When the ship is afloat, the rudder is partially supported in its bearings by its own buoyancy, amounting to some 1,660 lbs., and is lubricated by the surrounding water. This should give a smaller value for rudder friction (R) with ship afloat than with ship in dry-dock. On the other hand there was probably some additional force (W) required to move the surrounding dead water; this force as well as the effect of any tidal currents has been neglected.

In view of the above considerations, and since it is believed that the tests afloat represented more nearly, in every way, the conditions which

obtained on the subsequent turning trials, it was decided to use the data from friction measurements afloat in making corrections for friction (see curves I, II, and III, Fig. 17, Plate 127). The average deviation of points from the curve I is about 60 pounds, or 5 per cent of the stress at 25° helm. This means an error of less than 1 per cent at 28 knots speed and 35° helm.

As all turns were made with starboard helm, the two cases of greatest interest are:—

I. Ship under way, helm moving to starboard.

II. Ship under way, helm steady a-starboard.

Case I represents at its limit the condition at which maximum force was obtained. Then the friction of the rudder and the friction of overhauling B both tend to increase the tension in A, and consequently the dynamometer reading must be diminished by the amount of these forces to obtain the force to overcome moment of water-pressure on rudder, *i. e.*:—

$$D=\tfrac{1}{2}T+\tfrac{1}{2}R+B.$$

Or, subtracting from the dynamometer reading $(B+\frac{1}{2}R)$ (curve I) for proper helm-angle, we obtain the half value of force to overcome moment of water-pressure against the rudder.

$$\tfrac{1}{2}T=(D-\tfrac{1}{2}R-B) \tag{4}$$

Case II represents the condition which existed when the so-called "steady" value of stress (considerably less than the maximum) was obtained after the ship had turned through approximately 90°. With the helm stationary at a definite angle with the center-line of the ship, the frictional forces become static. The tension in lead A still holds the rudder against the turning force of the water. The rudder friction (R) opposes any motion of the rudder in either direction; and since it helps the tension in A to hold the rudder, the dynamometer reading should be increased by the amount of the force. The tension in B set up in overhauling, due to friction of sheaves, etc., opposes the pull in A and would therefore be subtracted from the dynamometer reading, *i. e.*:

$$D=\tfrac{1}{2}T+B-\tfrac{1}{2}R \tag{5}$$

However, any tendency of the rudder to move in one direction or the other would change these various frictional forces. At best, the effect of friction in the condition of "steady starboard" is somewhat indefinite, but is certainly diminished by vibration, as considered below.

When steaming on a steady course with helm amidships, the vibration at the stern of the ship was appreciable, but not all violent. On starting

a turn, when the helm was put over to the desired angle, at a fairly rapid rate (3° per second), the vibration did not increase materially up to the time when the dynamometer showed a maximum stress (approximately 12 seconds for 35° helm). Therefore it was considered that for the condition of maximum stress, the whole force of friction, as shown on curve I, was effective in opposing the movement of the rudder. Accordingly the reading of the dynamometer (maximum stress) was diminished by an amount taken from curve I (Fig. 17, Plate 127) for the given maximum helm-angle—

$$\tfrac{1}{2}T = D - (\tfrac{1}{2}R + B).$$

On the other hand, when the helm was steady a-starboard and the ship had turned through approximately 90°, with the dynamometer indicating a practically uniform stress, there was a marked increase in vibration of the ship's stern, possibly due to the impact of masses of water thrown successively against the rudder by the port propeller. It is certain that this violent vibration would materially diminish any static frictional forces in rudder bearings. Therefore it is believed that on steady helm, the correction for rudder friction ($\frac{1}{2}R$) amounting to +2 per cent ($\frac{200}{8000}$) of the maximum stress obtained, should be neglected. Furthermore, the static force in lead B would be reduced by continued vibration, and could not again reach its full value without further motion of the helm to starboard. The force in B could not act at steady helm, with the full value shown on curve II (Fig. 17, Plate 127). Accordingly, since we have no means of approximating the value of B in this condition of violent vibration on steady helm, and since neglecting this force entirely is to err on the safe side, overestimate,

$$D = \tfrac{1}{2}T + B - \tfrac{1}{2}R,$$

no frictional correction has been applied to the "steady" stresses obtained. The dynamic friction of the leads on 35° helm, as measured afloat, but without vibration, is 1,000 pounds. Assuming even as much as half of this to act under violent and continued vibration, the error introduced would be $\frac{500}{8000}$, which corresponds to a correction of −6 per cent. This correction, combined with the correction (+2 per cent) for rudder friction, gives a maximum net correction of −4 per cent which has been neglected. The error is probably not so great as this, and is on the safe side.

On the backing tests, the vibration was so violent as to shake down the boiler brick walls. Consequently it is believed that no value could be found in an analysis of friction forces under the backing condition.

APPENDIX VI.

SPEED-REVOLUTION CURVE.

The mean displacement of the Sterett on the turning trials as determined by change in draught from beginning to end of tests was 835 tons, *i. e.*, 93 tons or 12.7 per cent greater than the normal displacement (742 tons) on standardization, when the speed-revolution curve was obtained. Consequently, it was necessary to make a correction to this curve for the over-draught condition. Curves were obtained from the U. S. Model Tank at Washington, showing effective horse-power on speed for the Sterett model, at three displacements, viz., normal, 10 per cent below, and 10 per cent above normal. From these curves cross-curves at constant speeds were plotted as shown on Fig. 18, Plate 128, from which the effective horse-power was obtained for these speeds and at displacement 12.7 per cent greater than normal.

Curves of effective horse-power on speed in knots, for both normal and 12.7 per cent over-displacement, were then laid down as shown. The speed-revolution curve for normal displacement was also plotted on the same scale of speed. Then for a given speed, say 22 knots, the power on normal displacement (from curve I) is 2,450 effective horse-power and the corresponding revolutions per minute 414. For the same power, at 12.7 per cent greater displacement, a speed of only 21.7 knots would be obtained. Furthermore, a curve of per cent slip on speed in knots shows a very gradual increase of slip with speed. Consequently, for the small change of speed (22 − 21.7 knots) in going from normal to 12.7 per cent over-displacement, the slip may be assumed constant. Then for the same power and revolutions (414 revolutions per minute) the speed is reduced from 22 knots to 21.7 knots.

To obtain a new speed-revolution curve for the conditions of the trials, from the curves of effective horse-power and speed revolutions at normal displacement, a horizontal line *ab* of constant effective horse-power was drawn at an arbitrary point. At *a* the line *ac* was laid off vertically upward, equal in length to the intercept *bd*. This gave one point *c* of the new speed-revolution curve. The new curve of revolution was completed by a fair curve through a number of such points.

The record of revolutions shows a notch for each 10 revolutions of port

and starboard propellers; and the time record a notch for each $\frac{1}{4}$ second of time. To estimate the ship's speed in approaching the turn, time and revolutions over any chosen interval were counted on the record roll. Then, since time can be read to the nearest half-notch, *i. e.*, to $\frac{1}{8}$ second, and since the revolutions can be read to 0.1 space, or one revolution, the possible error in time for an interval of 30 seconds is $\cdot\frac{125}{30}$, or less than 0.5 per cent; and the possible error in revolutions is $\frac{1}{250}$, or less than 0.5 per cent. We may therefore conclude that the precision of revolutions per minute, as obtained from the record, is within 1.0 per cent.

APPENDIX VII.

TURNING TRIALS WITH ENGINES BACKING.

On completion of the "meeting ship" trials and the turning trials at various speeds ahead, tests were made to determine the turning moment developed by putting helm over with engines backing. Two sets of tests were made; first, two turns with engines backing under all available boiler power; and second, two turns with the engines backing under approximately half of the full boiler power. The full-power backing trials are of particular interest because in them the greatest twisting moment observed throughout the trials was developed. The vibration on these tests was so violent that no correction for friction was applied to the force recorded by the dynamometer.

On the first backing test, the engines were ordered "full speed astern," and, simultaneously, the helm was put 32° port. The twisting moment rose steadily for a period of $\frac{1}{8}$ minute to 75,080 lbs.-feet, then wavered and rose slowly for $\frac{1}{4}$ minute to a value of 136,500 lbs.-feet, fell off for a period of $\frac{1}{8}$ minute to a minimum value of 74,220 lbs.-feet, and then rose slowly for $\frac{1}{4}$ minute to a maximum value of 145,030 lbs.-feet. Without moving the helm the engines were ordered stopped and immediately ordered to "half speed ahead," the stress falling off abruptly as soon as the engines were stopped. During this turn, which occupied approximately $\frac{7}{8}$ minute, the revolutions of the port engine (which were fairly uniform throughout the turn) averaged 358.7 revolutions per minute. The revolutions of the starboard engine averaged 408 per minute.

On the second full-power backing test, the engines were first ordered to "full speed astern," and after the ship had gathered considerable sternway, the helm was again put over to 32° port. The twisting moment rose during the first $\frac{1}{4}$ minute to 111,550 lbs.-feet; during the second $\frac{1}{4}$ minute to 128,190 lbs.-feet; and at the end of $\frac{7}{8}$ minute from time of first putting helm over, to a maximum value of 149,090 lbs.-feet. The engines were then ordered to "half speed ahead." The helm was put amidships, the moment falling off rapidly. On this turn the vibration throughout the ship was so violent that the boiler brick walls of two boilers were shaken down. At the same time the quarter-deck was flooded with water so that the electrical connections to the special helm-angle indicator were useless. The

maximum helm-angle 32° was read off directly by an observer stationed aft for that purpose. During this second turn, which occupied 82½ seconds, the average revolutions while backing, but before putting the helm from amidships to port, were 297.1 port and 337.1 starboard. The average revolutions for a short period just after putting the helm over were 340 per minute port and 356 starboard, and at the end of 1 minute the revolutions averaged 400 per minute on both engines. The average revolutions for the turn, from the time of putting the helm over, were 378.9 per minute port and 379.6 starboard.

It is interesting to note that the maximum moment obtained on the backing tests is 57.9 per cent greater than the maximum obtained at 27.0 knots ahead, with 35° of helm.

After backing at full power, two turns were made at approximately half of full power, the helm being put over to 35° port after the ship had gathered sternway.

On the first turn the moment rose in ⅛ minute to a value of 77,630 lbs.-feet and remained nearly constant for ½ minute, then rose slowly to 84,040 lbs.-feet at the end of 1 minute, remaining steady at that value till the test was concluded. The average revolutions for 1 minute preceding the turn were 225 per minute port and 199 per minute starboard. During the turn the revolutions averaged 262 per minute port and 256 per minute starboard, both being pretty uniform during the turn.

On the second turn at reduced power, the moment rose in about ⅛ minute to 88,500 lbs.-feet, then more slowly for a period of ¼ minute to 95,980 lbs.-feet, the maximum; for the remaining ¼ minute of the turn the moment fluctuated between 79,980 lbs.-feet and 90,650 lbs.-feet. The average revolutions during the turn were about 288 per minute port and 283.2 per minute starboard.

DISCUSSION.

THE CHAIRMAN:—Gentlemen, the paper on "Rudder Trials, U. S. S. Sterrett," is now open for discussion.

PROF. W. HOVGAARD, *Member:*—The data given in this paper I consider of great interest, for experiments on this subject are, on the whole, badly needed. The modern increase in speed and length of ships has necessitated the use of very powerful steering gear, and experiments on such high speed vessels as destroyers are, therefore, of very particular value.

It is to be regretted that complete turning trials, including the determination of the various elements of the turning circles, were not undertaken at the same time

as the rudder experiments were made. That would have added greatly to the value of the experiments.

Referring to page 309, the conclusion of Wellenkamp there referred to, and advanced already by Pollard and Deibout, that the rudder angle should be reduced by the full amount of the drift angle, is certainly erroneous. According to an analysis which I have made of numerous turning trials,* the deduction should be much smaller than the drift angle. I agree, however, with the authors of the paper that the deduction should probably be some function of the drift angle.

The conclusions stated on pages 311 and 312 are certainly very interesting and, notably the numerical data, are decidedly novel. Conclusion 6 points strongly in favor of placing the steering engine right aft or at least in the engine-room. I never could see the advantage of placing the steering engine forward, as it requires very little looking after.

Mr. E. A. Sperry, *Member* (Communicated):—I consider this paper a valuable contribution to our knowledge on the subject under discussion. It has, however, occurred to me that the value of the results would have been somewhat increased had the sheet of curves in Fig. 9, Plate 119, incorporated upon its face and actual curve of the angles in azimuth made by the ship while turning in response to various positions of the helm. This could have been quite easily accomplished by using the gyro-compass repeater or by gyro apparatus similar in all respects to that employed by the Navy Department for recording angles of pitch and roll, but so arranged as to record all yawing movements, or movements in azimuth. Such an apparatus has been devised whereby the angles are quite minutely traced, representing as they do the circumference of a 10-foot circle, where a single degree is represented by about an inch travel of the pen. A curve of this kind would have served to give us the exact characteristic of the curve of response at various rudder angles, together with the time lag and also the relative resulting velocities of movements in azimuth.

I wish to congratulate the authors upon the ingenuity of the apparatus employed, together with its general arrangement on the ship; also upon the mass of data accumulated in this paper, which I believe will be a valuable contribution to our proceedings.

The Chairman:—It is to be regretted that a paper of this character, as well as those which are to follow, should have such scant attention, owing to the lateness of the hour; but I know that all the members who are interested will read them when they appear in the Transactions, and I know that you will permit me to extend the thanks of the Society to the authors of the paper which has just been presented for the very admirable work they have done.

We will now have read to us the paper entitled, "Logarithmic Speed-Power Diagram," by Mr. Thomas M. Gunn.

Mr. Gunn presented the paper.

*See Transactions of Institute of Naval Architects, London, 1912.

LOGARITHMIC SPEED-POWER DIAGRAM.

By Thomas M. Gunn, Esq.

[Read at the twentieth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912.]

To logarithmic diagrams of one type or another the modern engineer is indebted for the rapid and easy solution of many cumbersome formulæ. The calculations which yield themselves most readily to its use are those involving products, quotients, or powers of numbers. It matters little what the exponent is, the solution of a formula consisting of (a constant) × (a variable) raised to any known power, requires for its repeated solution only the drawing of one straight line, and thereafter, for any value of the variable within the range of the diagram, the result is read off directly. For such purposes it is common to use logarithmic co-ordinate paper, which is available in two or three sizes. Diagrams have already been used repeatedly for the calculation of frictional resistance of ships.

It is not desired in this paper to present new information upon the power of ships or propellers, but rather to submit a means of convenient application of the laws of comparison for ships and propellers. The diagram used cannot be shown here to such a scale as to make it sufficiently accurate for calculations where very close approximation is required; the principle, however, will be shown so that large scale diagrams may be made to suit the individual needs.

The following table summarizes some of the commonly known relations between similar ships of different size. For convenience, all of these relations are stated in the last column in terms of speed.

Function.	Quantity in proportion to which function varies, in terms of:		
	L.	D.	V.
Length or other linear dimension, L....	L	$D^{\frac{1}{3}}$	V^{3}
Surface, S.....	L^{2}	$D^{\frac{2}{3}}$	V^{6}
Speed, V.....	$L^{\frac{1}{2}}$	$D^{\frac{1}{6}}$	V
Displacement, D.....	L^{3}	D	V^{9}
Wave resistance (residual).....	L^{3}	D	V^{9}
Wave power.....	$L^{\frac{7}{2}}$	$D^{\frac{7}{6}}$	V^{21}

The fact that both the exponent and coefficient of friction vary in the formula for frictional resistance makes it impossible to introduce this term directly in the laws of comparison. Detail calculation shows that if frictional horse-power be calculated for two similar surfaces at corresponding speeds, the ratio of horse-power is very closely approximated by the 6.735 power of the speed-ratio, or the 3.3675 power of the length-ratio. (See appendix.)

This relation holds most closely for surfaces above 50 feet in length, but is a good approximation even as low as 10 or 15 feet in length.

Since friction power of the ship varies nearly as the 6.735 power and residual power as the 7th power of the speed for similar hulls at corresponding speeds, it may be expected that their sum, or effective horse-power, will vary as some power of the speed between 6.735 and 7. It is somewhat variable, dependent upon the ratio between frictional and total resistance or power, as indicated approximately below:—

Ratio $\frac{F.\,H.\,P.}{E.\,H.\,P.}$	*Exponent of V for converting E. H. P.*
.0	7
.20	6.944
.40	6.895
.50	6.871
.60	6.847
.80	6.798
1.00	6.735

In common practice, the power consumed in surface friction is from 50 to 60 per cent of the effective power, as low as 40 per cent only in very high-speed craft, and dropping possibly to 10 per cent in hydroplanes or rising to 90 per cent at low speeds for long cargo vessels. It may be stated that for normal designs, from full boats of low speed to fine forms of high speed, there is not much error in assuming the exponent of reduction to be about 6.866.

Errors due to this assumption are discussed in the appendix.

Proceeding to the application of the logarithmetic diagram to these calculations; on the "Foundation Sheet," Plate 129, is a set of logarithmic co-ordinates so drawn as to cover a convenient range for calculation. The main variable which is used as abscissa in all cases is arbitrarily chosen to be speed, V, in knots (see bottom of diagram). The scale of ordinates is marked "Horse-power" but is also used for reading displacement, length, beam, draught, wetted surface, or other dimensional quantities.

The diagonal lines, which may be called reference lines, are laid out to such slopes as to give numbers proportional to the following powers of speed:—2, 2.83, 3, 4, 6, 6.735, 6.866, and 7. Of these, the first is proportional to length or any linear dimension. The fourth power of speed is proportional to wetted surface or any area measured on the ship. Displacement or volume is proportional to the 6th power.

For any type of ship for which full-power data is available a diagram such as Fig. 2, Plate 130, may be constructed, which are to be superposed on Fig. 1, Plate 129. Ordinarily tracing cloth would be used for the diagram corresponding to Fig. 2, Plate 130. On this is seen a diagonal marked "Shifting Line." This is to be placed upon the "Shifting Line" on Fig. 1, Plate 129. It will now be observed that a vertical line on Fig. 2, Plate 130, marked "Displacement" intersects, at some point, the line marked similarly on Fig. 1, Plate 129. To the left of this point on the margin of Fig. 1, Plate 129, will be read the displacement of the vessel. Similarily length may be read to the left of the intersection of the two length lines; likewise for wetted surface. Other desirable dimensions may be shown, such as beam and draught. Next, the curve marked effective horse-power on Fig. 2, Plate 130, reads directly for any speed, the corresponding effective horse-power by reference to the speed scale at the bottom and the power scale to the left of Fig. 1, Plate 129. The assumption is that the effective horse-power varies as the 6.866 power of the speed, for two similar vessels at corresponding speeds.

If now a similar boat of another length or displacement is desired, it is only necessary to shift Fig. 2, Plate 130, on Fig. 1, Plate 129, being careful that the shifting lines still coincide, until the desired displacement or length is obtained. From the effective horse-power curve, the power required for the new vessel may be read directly.

Assuming that the propulsive efficiency is the same for similar ships it will be equally correct to plot the indicated horse-power, as has been done on Fig. 2, Plate 130.

The convenience of this method of conversion from one size to another is quiet evident. For each boat or series of boats a separate sheet should be used.

To further illustrate and to show some results of comparison available by this method Figs. 3 to 7, Plates 131 to 135, are given, showing a number of types taken from actual designs or from hypothetical designs which have been worked out from Mr. Taylor's standard series experiments.

If it is desired to compare two models at the same displacement it is only necessary to superpose the two and bring shifting lines and displacement

lines to coincide. If the comparison is to be on the length basis, the shifting lines and length lines are brought together.

Each model should be adequately described on the sheet bearing its power curve. In the illustrations are given the block coefficient, prismatic coefficient, ratios of beam to draught and length to beam and the displacement length coefficient, which may be described as the displacement in tons of a model of the ship 100 feet in length. Other means of describing the model, such as a reproduction to some standardized scale of the curves of immersed areas and water-line, may be used.

It is to be noted, as shown in the appendix, that errors involved in this method are small provided the ratio of reduction is not large. If the curve is correct for a boat 200 feet long the curve may be used for boats from 50 to 800 feet in length with close approximation. Reduction directly, however, from a model 15 feet long to a boat 600 feet in length would incur considerable error. It is then advisable to draw for the model the curve of residual horse-power, using for a shifting line V^7, and reduce this to a full-sized boat; and by separate calculation or curves to reduce the frictional power, then add the two after reductions so as to construct the effective horse-power curve of the full-sized ship.

Once this curve is constructed for a large vessel, the error of conversion from one size to another will be small.

The screw propeller also yields readily to analysis by means of this diagram, illustrated by Fig. 8, Plate 136. For this purpose the line marked V^7 on Fig. 1, Plate 129, should be used as shifting line. Probably this is not absolutely correct, but it is customary in propeller calculations to assume that the power ratio of two similar propellers at equal slip is as the ratio of the diameters with an exponent of $\frac{7}{2}$ when the relative speeds of advance are as the square root of the diameter. This would theoretically be exact if it were not for friction, which, as in the case of the ship, does not follow the laws of comparison. In this case, however, surface friction is a much smaller fraction of the total power, and the assumption of the exact exponent probably is as well as can be done at the present time.

On the power sheet for the propeller (Fig. 8, Plate 136), in addition to the shifting line, are shown lines for diameter and pitch, which are read by means of Fig. 1, Plate 129, at the intersection of these lines respectively with the length line, V^2, of Fig. 1, Plate 129. The projected area (or developed area if known) is represented by another line which is read at its intersection with the surface line, V^4, of Fig. 1, Plate 129.

In the case of the propeller whose characteristics are represented on Fig. 8, Plate 136, the experiments in the model tank (described in Professor

Peabody's paper "Experiments on the Froude") were run at 5 knots speed of advance. To construct Fig. 8, Plate 136, the curves of propeller thrust were reduced to effective horse-power, and for convenience, slip (s) was reduced to the coefficient K, which is $101.3 \div (1-s)$. With the sheet superposed upon Fig. 1, Plate 129, the points are marked at 5 knots speed corresponding to the respective values of K and of efficiency. Through the former points diagonal lines are drawn parallel to the line on Fig. 1, Plate 129, marked V^3, and each line marked with its respective value of K. The scale for efficiency is now constructed by projection from the points for efficiency which have been marked at 5 knots, in a direction parallel to the lines for K. Now, since experiment has shown that, within limits, a given propeller has constant efficiency at constant slip, and that its power varies as the cube of speed of advance, we may take any speed of advance for this propeller, and any effective power, and read the value of K, and, by diagonal projection, the value of efficiency. From K, speed of advance, V, and pitch, P, the revolutions per minute, R, are ascertained by the formula—

$$R = \frac{V}{P} \times K.$$

In the case of design, if it is found that the revolutions per minute so found are too high, the diagram, Fig. 8, Plate 136, may be shifted upward on Fig. 1, Plate 129, giving a propeller of larger diameter, and for the desired speed of advance and power the efficiency and revolutions are again determined, and the process repeated until a desired speed of revolution is obtained. In this process, of course, the shifting line of Fig. 8, Plate 136, is kept superposed on line V^7 on Fig. 1, Plate 129. In case of designs where the revolutions per minute can be made to suit the propeller, it is only necessary to shift until the line of best efficiency passes through the required speed of advance and effective power.

A sheet such as Fig. 8, Plate 136, represents the performance of only one series of propellers, all geometrically similar. If the pitch ratio or the width ratio is changed it is necessary to construct a new sheet. It is not difficult, however, to conceive an arrangement by which a series of types may be shown on the same sheet.

In the application of this propeller data to the ship certain precautions are necessary, as in all methods of propeller calculations, three of which will be mentioned.

(a) The speed of advance of the propeller through the surrounding water is not equal to that of the ship, due to the wake. This can only be estimated by comparison with other cases, or determined by model tank experiment.

(*b*) The effective power delivered by the propeller is not equal to the effective horse-power required to tow the ship with the propeller present and operating, but is usually less, due to the wake.

(*c*) The power required to drive the ship is not the same as if the propeller were not there, but is usually greater, due to pressure effects upon the hull, or stream line effects.

The thorough analysis of these three and other effects cannot be made for every case, however valuable it might be were it possible. It seems, then, that rather than make three involved guesses it might be as well to determine, from previous tests, a single coefficient. This might be termed an apparent wake. Superpose the propeller sheet upon the power sheet for the ship, and the whole upon the foundation sheet, bearing in mind that the shifting lines are not the same for the two. From trial, the speed and actual revolutions are known. From the model the effective horse-power is known. For the known speed of the ship find the effective horse-power, and for the propeller find the speed of advance which both gives this same horse-power and at the same time gives the number of revolutions known to have existed on trial. The difference between these speeds, divided by the speed of the ship, may be termed apparent wake, a quantity which may be used upon somewhat similar designs at corresponding speeds.

Following are the results from such a calculation upon the U. S. S. Manning and propeller by means of this diagram, together with results of more careful analysis by the same means, on the assumption of 90 per cent hull efficiency, as in Professor Peabody's paper.

Speeds (knots)	16	14	10
Revolutions per minute	152	127.7	86.3
Effective horse-power from model	1,360	775	231
Apparent wake (per cent)	3.8	5	9
Corresponding propeller efficiency (per cent)	68.1	68.1	67.9
Corresponding shaft horse-power (*A*)	1,998	1,139	340
Assuming 90 per cent hull efficiency:—			
Wake (per cent)	6.2	7	9
Propeller efficiency (per cent)	67.8	68.1	68.1
Power delivered by propeller	1,410	795	232
Power delivered by shaft (*B*)	2,080	1,169	341
Per cent excess of (*B*) over (*A*)	4.1	2.7	.3

It will be noted that this does not eliminate the difference between wake gain and thrust deduction, for which, apparently, in this case allowance must be made as high as four per cent at the higher speeds.

This question of the interaction between hull and propeller is as much a matter of doubt in other methods of procedure as in the present case, and is dependent upon so many factors that it cannot be predetermined with certainty.

To assist in determining under what conditions cavitation will take place contours are shown on Fig. 8, Plate 136, for a coefficient which, multiplied by diameter in feet, gives the propulsive thrust per square inch of projected area. As has been shown by Mr. Taylor and others, this is not a perfectly safe criterion for judging as to cavitation, and must be taken in conjunction with tip velocity, as well as many other things. It is, however, of assistance to know the value of this thrust per square inch for comparative purposes.

APPENDIX.

DEGREE OF ACCURACY OF THE LOGARITHMIC POWER DIAGRAM.

To show that power consumed by surface friction varies almost as the 6.735 power of the speed for similar vessels at corresponding speeds within a certain range of length, the following tabular calculations, based upon a hypothecal series of ships, all similar and running at corresponding speeds, are given:—

Length.	Wetted surface.	f	n	Speed.	Friction horse-power.
9	8.1	.01130	1.853	3	.00631
25	62.5	.01050	1.844	5	.192
49	240	.01008	1.8365	7	1.838
100	1,000	.00974	1.83	10	20.20
225	5,062	.00940	1.83	15	312
400	16,000	.00917	1.83	20	2,164
625	39,062	.00898	1.83	25	9,730

Comparing these in pairs, the following results are obtained:—

Lengths.	Ratio of speeds.	Ratio of friction powers.	Corresponding exponent of speed.
9 and 25	5/3 =1.667	.192/.00631 =30.4	6.685
9 and 100	10/3 =3.333	20.20/.0063 =3,202	6.71
9 and 400	20/3 =6.667	2164/.00631 =343,500	6.715
25 and 49	7/5 =1.4	1.838/.192 =9.58	6.72
25 and 225	15/5 =3	312/.192 =1,624	6.735
25 and 625	25/5 =5	9730/.192 =50,650	6.735
49 and 100	10/7 =1.428	20.20/1.838 =11.05	6.74
49 and 400	20/7 =2.857	2164/1.838 =1,123	6.73
100 and 225	15/10=1.5	312/20.20 =15.44	6.75
100 and 625	25/10=2.5	9730/20.20 =482	6.73
225 and 625	25/15=1.667	9730/312 =31.15	6.735

Calculations at other speeds give the same results with slight variation for the smaller sizes, below 50 feet.

From such data as above, the conclusion was reached that at corresponding speeds for similar vessels the ratio of friction power is as the 6.735 power of the speed ratio (or 3.367 power of the length ratio, or the 1.1225 power of displacement ratio) for vessels of 50 feet or over, and that it is fairly approximate for lengths of 25 or even 10 feet.

Regarding errors due to the assumptions made in the paper the following calculation will give some indication.

The error will depend upon the ratio of reduction (ratio of lengths) and on the error in the exponent. The highest actual exponent found by the author for a very high-speed motor boat was 6.94. By going to extremely low speeds, cases are found where practically all resistance is friction, so that the exponent is near 6.735, but for cases where it would be important to know the power, the author has found no instance where the true exponent is below 6.79.

Regarding these as the extreme departures from the average value, 6.866, the following table gives extreme errors due to the assumption of the latter. A column is also given for the per cent within which the large majority of boats are found, at speeds between .8 and 1.5 × square root of length.

Ratio of lengths.	Extreme error.	Normal maximum error.
	Per cent.	*Per cent.*
1.5	1.5	.7
2	2.6	1.2
3	4.1	1.9
5	6.1	2.8
10	8.8	4.0
20	11.7	5.4
40	14.6	6.7

It may be noted here that such errors as are given above are not negligible for large ratios of length. For a 500-foot boat, the results from a 12-foot model should not be reduced by the single shifting line, but be treated as previously suggested. If a curve is made correct for a length of 250 feet and is used for boats from 125 to 500 feet in length, it need not be expected that the error will reach one per cent at important speeds, and can scarcely be as large as 2½ per cent in extreme cases.

DISCUSSION.

THE CHAIRMAN:—Does anyone desire to discuss the paper presented by Mr. Gunn? Apparently not. It is a paper which will be read with great interest, I am sure, later on by members of the Society. With your permission, the thanks of the Society are extended to Mr. Gunn for this interesting paper.

The last paper on our program is entitled "Tool Steel for the U. S. Navy," by Mr. Lewis Hobart Kenney, member of the Society. In view of the lateness of the hour, I will ask Mr. Kenney to read the paper by title and to refer briefly to the most salient features. I am sure that all of us will take pleasure in reading the paper later on when it appears in the published volume of the Proceedings.

Mr. Kenney presented his paper in brief abstract.

TOOL STEEL FOR THE UNITED STATES NAVY.

By Lewis Hobart Kenney, B. S., M. E., Member.

INTRODUCTION.

Previous to 1909 each navy yard prepared requisitions for the purchase of tool steels for its own purposes. The requisitions specified either that proprietary material be purchased or that the award of contract be based on information obtained by a test of some description on samples submitted by the bidders. But by this method there could be no uniformity in the specifications of the navy yards, so in order to centralize the purchasing and to standardize the tool steels, a tool steel board, in 1909, recommended that the Philadelphia Navy Yard be the purchasing station; and it prepared specifications for one "high speed" and for three grades of carbon tool steel. The specifications are given in Appendix A.

The chemical composition of this "high speed" tool steel differed from that of any of the commercial tool steels, but the chemical composition of each grade of carbon tool steel corresponded to that of commercial tool steels. The three grades of carbon tool steel varied principally in the carbon content, in order to adapt them to the purposes for which such tool steels are generally used. The contracts were awarded under these specifications to the lowest responsible bidders for tool steel of a chemical composition within the specification limits. The specifications required, as a part of the inspection for acceptance of the material, physical tests in addition to chemical analyses; but these physical tests never gave satisfactory or decisive results, and proved conclusively that it was advisable to revise the specified chemical compositions. The specifications did not provide a means for ascertaining the relative merits of the tool steels offered by the bidders or for learning if there were tool steels superior to those within the limits of the chemical compositions specified.

In order to overcome the above objections, it was considered advisable to revise the specifications given in Appendix A. Such specifications should require the bidders to submit samples of the tool steels which they offer. The samples should be manufactured into tools and subjected to physical tests devised to investigate their relative merits. The data thus obtained should form the basis for recommending the award of contract. The chemical compositions should be given with maximum and minimum limits, in order to indicate to the bidder the kind of tool steel required, but as the

physical test would form the basis for recommending the award of contract, a statement should be included to the effect that the bidders could submit samples of chemical compositions differing from those specified. One object of these provisions was to introduce competition as to the qualities of the tool steels instead of competition simply in price, and another object was to provide a means for learning something of the relative merits of the commercial tool steels, and for taking advantage of the developments and progress made by the manufacturers in this industry. By this means definite information could be obtained concerning the qualities of the tool steels before the contracts were awarded for their purchase. The possession of such information is unquestionably of the most vital importance in preparing a recommendation for award of contract.

The study of tool steels, which the adoption of specifications as outlined above made possible, is under the direction of the Engineer Officer, Navy Yard, Philadelphia, Pa. The subject is practically divided into the two general classifications of "high speed" tool steel, or tungsten tool steel, class 1, as it has been designated in the later specifications, and carbon tool steels. The "high speed" tool steel was considered the more important and its study was, therefore, undertaken first. In order to eliminate repetition this paper has been divided into the following sections:—

(*a*) Tungsten tool steel, class 1, development of specifications.

(*b*) Carbon tool steels, development of specifications.

(*c*) Description of selective tests.

(*d*) General notes.

Sections (*a*) and (*b*) have been subdivided to represent the successive schedules under which tool steels were purchased. Only "high speed" tool steel was purchased under Schedule 3244, but tungsten tool steel, class 1, and carbon tool steel, classes 1, 2, 3, and 4, were purchased under Schedules 3893 and 4469.

TUNGSTEN TOOL STEEL, CLASS 1.

Schedule 3244.—The first revision of the tool steel specifications in accordance with the scheme outlined above was for the purchase of "high speed" tool steel for the U. S. Naval Academy, the specifications for which are given in Appendix B. The limits of the chemical composition were varied from those given in the existing specifications (Appendix A) in order to permit bidders to submit proposals on their commercial standard tool steels, and the feature of a selective test was introduced. The selective test provided means for investigating the relative suitability, for the purposes

intended, of the tool steels offered by the bidders, and the recommendation for award of contract was based on the information thus obtained. In order to obtain samples of tool steel for the selective test the specifications required each bidder to furnish a sample bar of the tool steel he offered; and this sample bar was delivered to the engineer officer for him to direct the selective test. The heat treatment of the tools, their chemical analysis, the conditions of the physical test, and the computations necessary to determine the award of contract constitute the selective test. A lathe tool selected for the physical test was kept cutting, without lubricant, until it failed by the sudden breaking down of the cutting edge due to heating caused by the friction of the chip; and a record of the elapsed time of run, or cutting life of the tool, was made. By keeping the other conditions constant the elapsed time of run was the principal variable. Each tool after failure was reground, care being taken to remove the effects of the heating due to the previous cut, and again tested until the tool broke down as above described, after which it was reground and tested a third time.

It was considered that the cutting life, as shown by the elapsed time of run above described, and the cost of the material were the principal factors in determining a selection, because the number of times the tools could be reforged and reground, and the cost of keeping them in efficient condition, would be practically the same regardless of the quality of the tool steel. Therefore the ratio of the arithmetical mean of the elapsed time of all runs of the tools of one sample to the price per pound of the material was computed. It was recommended that the contract be awarded for the purchase of the tool steel of highest "ratio." The data of this selective test are given on sheet No. 607, Plate 141.

An estimate was made to determine the relative values of the several tool steels tested by computing, first, the value for each sample which would give it a "ratio" equal to the highest "ratio," and second, to determine the value of the tool steel of highest ratio to obtain a ratio equal to that of each sample. The values thus computed are given on sheet No. 607, Plate 141.

A test under the conditions prevailing during the above selective test was made of tool steel which had been purchased under specifications, Appendix A, from four contractors in order to learn if it were equal or superior to the commercial tool steels which had just been subjected to a selective test; and it proved conclusively that some of the commercial tool steels were superior. The data of this test are given on sheet No. 607, Plate 141.

Schedule 3893.—The information obtained from the selective test under Schedule 3244 indicated that it was advisable again to revise the specifica-

tions for the following reasons:—First, to more clearly explain the requirements to the bidders, and second, to utilize the information obtained in preparing more rigid specifications.

The analyses of the sample bars submitted under Schedule 3244 were utilized in preparing the chemical compositions for the specifications, and the limits of the elements were made broad enough to include the best grades of "high speed" tool steel. For purposes of classification, the "high speed" tool steel was designed as tungsten tool steel, class 1, in the specifications.

These specifications, which are given in Appendix C, required a selective test similar in character to that previously described. The purposes for which the tool steels are, in general, adapted was inserted in the specifications to assist navy yards in selecting tool steels adapted to their needs, and also as a guide for bidders in case they should desire to submit, for selective test, tool steels of a composition differing from that specified. The conditions throughout the selective test were kept as nearly uniform as facilities would permit so that the principal variable was the elapsed time of run, or cutting life of the tool. With all the care exercised, variations in the elapsed time of run occurred for each sample, and, in order to determine if any of the observations of the elapsed time of run should be rejected, they were adjusted by the principles of least squares.

During this test a volt meter and ammeter were used to determine the input to the motor which drove the test lathe, in order to obtain a measure of the work done by the nose of the tool. The ammeter readings varied for the different tools, due principally to slight variations in depth of cut and cutting speed, which indicated that the work done by the different tools was not the same, and in order to allow for this difference in computing the selective factor a quantity was introduced called "work value," which is the product of the mean elapsed time of run of all tools of one sample and the mean watts required to drive the lathe minus the friction watts. The work value, therefore, is the watt-minutes of work done by the tool.

The "work value" divided by the price per pound of the material gave the selective factor for this test. The relative values of the tools steels were computed as previously described, and the data of this test, together with the chemical analyses of the tool steels, are given on sheet No. 1058, Plate 142,

Schedule 4469.—Another revision of the specifications was considered necessary after the above selective test had been completed, in order that advantage might be taken of the additional information obtained, and the feature of a selective test was continued. The new specifications are given in Appendix D.

The selective test was conducted under uniform conditions as previously described, so that the principal variable was the elapsed time of run of the

tools. Electrical observations were made of the input to the motor which drove the test lathe. They showed, as on the previous test, that the work done by the tools varied. It was therefore decided to compute the "work value" or watt-minutes of work done by each tool first, and then adjust the "work values" by the principles of least squares instead of elapsed time of runs, as was done in the previous test. By the previous method an observation of the elapsed time of run of a tool might vary so greatly from the mean that it would be rejected, although the watt-minutes of work done by a tool might not vary sufficiently from the mean work value to necessitate rejection. The work done by a tool, which is indicated by the elapsed time of run and the watts consumed, is an important factor in determining selection, and it was therefore decided that the "work value" of each tool was a fairer value to adjust by the principles of least squares than the elapsed time of runs. The relative values of the tool steels were computed as previously explained, and the data of this test, together with the chemical analyses of the tool steels, are given on sheet No. 1520, Plate 144.

A test was made of the tools which obtained the highest selective factor under Schedule 3893 under the same conditions as the above selective test, and the data are recorded under the heading "4 Schedule 3893" on sheet No. 1520, Plate 143.

CARBON TOOL STEELS.

Schedule 3893.—The information obtained from the selective test conducted under Schedule 3244 indicated that it was advisable to revise the specifications for carbon tool steels given in Appendix A, and a selective test similar in character and purpose to that previously described was introduced. Four classes of carbon tool steel were selected which varied principally in their carbon content. The specifications finally prepared are given in Appendix C. The conditions throughout the selective test were maintained as nearly constant for each class of tool steel as facilities would permit, and the elapsed time of run, or operating life of the tools, was the principal variable in the test, because the tools were operated until they broke down.

The milling cutters for the selective test of carbon tool steel, classes 1 and 2, are shown on sheet No. 1058, Plate 142. These cutters were operated until they broke down either in the shank or teeth. The elapsed time of run of the cutters was recorded and represents the total time the cutters were operating, but does not include the time required to return the milling machine table to the starting point and to set for the next cut. The selective factor represents the ratio of the mean elapsed time of run of all cutters of one sample to the price per pound of that sample.

The selective test tool for class 3 carbon tool steel was a pneumatic cape chisel, shown on sheet No. 1058. The chisels were operated until they failed either by the breaking of the cutting edge, dullness or wearing of the sides, so that the length of the cutting edge was reduced. The chisels were reground and given a second test, and the total distance cut was recorded. The selective factor represents the ratio of the mean distance cut by the chisels of one sample to the price per pound of that sample.

A button-head rivet set was used as the selective test tool for carbon tool steel, class 4, and is shown on sheet No. 1058, Plate 142. The sets were tested by driving a certain number of hot rivets, and their condition after the test was observed and a record made of the comparative conditions. No selective factor was computed because the test is not so decisive as the preceding tests, but this class of tool steel is, of course, not intended for cutting tools.

The data of the selective tests, the chemical compositions, and the relative values computed for the above classes of carbon tool steel are given on sheet No. 1058, Plate 142.

Schedule 4469.—After the selective test of Schedule 3893, it was considered advisable to revise the specifications for reasons similar to those previously given. The new specifications are given in Appendix D.

The conditions throughout the selective test were maintained as nearly uniform as facilities would permit, and the operating life of the tools determined as previously described. Before the tools were treated a determination was made of the decalescent point of each sample to assist in selecting suitable treating temperatures. The heating and cooling curves of the samples are given on sheet No. 1521, Plate 144.

Some of the bidders took advantage of the clause in the specifications which permitted tool steels to be submitted of a chemical composition differing from that specified. Tool steels containing tungsten were submitted under carbon tool steels, classes 1 and 2, and a tool steel containing chromium was submitted under carbon tool steel, class 3.

The selective test tools used are shown on sheet No. 1521, Plate 144, and it will be noted that the milling cutter is the only one changed from the selective test tools shown on sheet No. 1058, Plate 142. The change in the milling cutter was made in order to support the outer end so that it could better withstand the strain of the test. The method of conducting the selective test was similar to that described for the preceding schedule. It was at first intended to adjust the observations of this test by the principles of least squares, but the variations of the observations were such that it was decided the results thus obtained would not warrant the labor involved.

Observations, therefore, which were considered to be not fairly representative, were rejected.

The specifications, Appendix C, contain a tungsten tool steel, class 2, which was intended as an intermediate tool steel between the carbon tool steel, class 1, and the tungsten tool steel, class 1, but it was omitted from the specifications, Appendix D. A small quantity of tool steel under these specifications had, however, been purchased, and in order to learn how it compared with the tool steels tested under the above selective test, milling cutters were made, treated and tested under identical conditions.

The data of the selective tests, the chemical compositions and the relative values computed for the above classes of carbon tool steel are given on sheet No. 1521, Plate 144.

DESCRIPTION OF SELECTIVE TESTS.

Tungsten Tool Steel, Class 1.—The five tools made from the sample bars are stamped with the schedule number, with an index number which is assigned to each sample, and with consecutive numbers for the tools of one sample. All tools are hand-forged to the No. 30 lathe tool form of the Sellers system of tool forms. The following day the tools are treated, two furnaces being required for this purpose. In one furnace a temperature of 1,600° to 1,700° F., and in the other a temperature of 2,400° to 2,450° F., are maintained. The cutting ends of the tools are uniformly heated in the low-heat furnace and then in the high-heat furnace. The temperatures given above do not indicate the temperature of the cutting end of the tool because the temperature is lower there than where the thermo-couple is. Uniform heat treatment is difficult to attain owing to the existence of a temperature gradient in the tool itself and the heat loss through the opening of the furnace for the insertion of the tool, resulting in a sharp temperature gradient at the opening of the furnace. In order to reduce the heat losses and the temperature gradient to a minimum and to obtain a satisfactory temperature for treating the cutting end of the tool, it is necessary to close with bricks the opening into the furnace so that it is just large enough to admit the tool. After the tools are removed from the high-heat furnace they are cooled by dipping the cutting end into oil, or they may be cooled by directing on it a heavy blast of compressed air. The oil is agitated by compressed air and is cooled to maintain a constant temperature. Oil was used for these tests and is considered preferable because it is less noisy and less expensive than compressed air, and tests which have been made indicate that better results are obtained by oil cooling. The tools are cooled in the oil until they are black hot, when they are removed and placed on a cooling table.

After the heat treatment the tools are ground to the No. 30 Sellers system of lathe tool forms and later tested on a nickel-steel forging. All tools of a selective test are tested on one forging because it has been impossible to obtain nickel-steel forgings of identical characteristics chemically and physically. The depth of cut, feed and cutting speed are constant throughout a selective test so that the principal variable is the elapsed time of run, or the cutting life of the tools. All tools are tested to destruction, after which they are reground and retested until each tool has been tested three times.

The action of the tools when cutting is very interesting, indicating that the material is torn from the forging instead of being cut. The chip wears at first a depression in the face of the tool back of the cutting edge, and the heat generated by the friction of the chip softens the tool. The generation of heat and wearing away of the tool continue until the depression, increasing in size, finally reaches the cutting edge, which suddenly breaks down and concludes the test for that tool. The action of the chip is shown on Plate 137. It is necessary to grind off about $\frac{3}{32}$ of an inch from the top and end of the tools to remove the effects of heating.

A volt meter and ammeter were used and later a graphic watt-meter to determine the input to the motor of the test lathe. By this means the average watts of the friction and cutting loads, which were found to be nearly constant, were determined; the difference being the net watts which, multiplied by the elapsed time of run of the tool in minutes, gave the work done by the nose of the tool measured by the resistance the forging offered to it.

The elapsed time of run for a tool depends somewhat upon the dissipation of heat generated by the friction of the chip. The dissipation is accomplished by conduction in the tool and forging and by radiation, since no lubricant is used. It has been noted generally that the steel forgings on which the tools are cutting will heat up considerably if they are of small diameter and operated at a high number of revolutions per minute. The elapsed time of run decreases as the temperature of the forging which the tool is cutting increases, and tests made when the room temperatures are far apart are not readily comparable. Also, due to the differences in the test forgings used, the selective tests conducted from time to time are not readily comparable.

Carbon Tool Steels.—Each sample submitted for selective test under Schedule 4469 was tested to determine the decalescent point. The heating and cooling curves are given on sheet No. 1521, Plate 144. All tools were heated to a temperature slightly above the decalescent point and quenched

in brine, after which the temper was drawn in a lead bath. The cutting tools were then ground and were ready for the selective test.

The proportions of the milling cutter used for the selective tests for carbon tool steel, classes 1 and 2, shown on sheets Nos. 1058 and 1521, Plates 142 and 144, were adapted from an article by Mr. A. L. Deleeuw, in the Transactions of the American Society of Mechanical Engineers. The principal difference from milling cutters in general use is in the comparatively small number of teeth permitting a larger clearance for the chips. This cutter is so small that it was necessary to support the outer end to enable it to stand the heavy cut desired to give a break-down test similar in purpose to that developed for tungsten tool steel, class 1. The cutter was operated at the speed of 370 revolutions per minute, feed 20 inches per minute, and 0.08 of an inch depth of cut through the full table travel of the milling machine. The table was run back to the starting point and reset as often as necessary until the cutter failed. The cutter was run without lubricant in order to make the test as severe as possible and there was a generation of heat similar to that developed by the tungsten tool steel, class 1, test, and blue chips were occasionally produced. The cutters made of carbon tool steel would become so hot that they would twist off in the cutting part of the tool, but the cutters made of tool steel containing tungsten, although operating at equal temperatures, would twist off in the shank. The former phenomenon is due to the drawing of the temper of the carbon tool steels, but the introduction of tungsten apparently prevents this action, enabling the tools to withstand heat break-down. The cutting edge of the tools containing tungsten would dull gradually, thereby increasing the tortional stress which ultimately equalled the physical strength of the material. The effect of tungsten is also shown in the greatly lengthened elapsed time of run or cutting life of the tools. The cutters are shown on Plate 138.

The heat treatment for these tool steels containing tungsten is not different from that of carbon tool steels; so that their introduction to the navy yards will cause no change in the present methods of treating tool steels, and there will be the added advantage of a much superior cutting tool steel.

The cape chisel used for the class 3 carbon tool steel selective test is shown on sheets Nos. 1058 and 1521, Plates 142 and 144. In some of the early tests and in the yard generally trouble was experienced by the occasional breaking of the shank of the hammer end of the chisel. But this trouble has been overcome so far as the selective tests are concerned, and reduced so far as the yard is concerned by treating about half an inch of the hammer end of the body with the shank and quenching by dipping about

three-fourths of an inch of the shank into brine for a few seconds, and then the entire tool. The cutting end is treated at the same temperature as the hammer end and the temper of both ends drawn by submerging the chisel in a molten lead bath at the desired temperature. One of the samples submitted under this class contained chromium, and the heating and cooling curve showed that a higher temperature was needed for treating, and the test showed that the temper should be drawn at a higher temperature than for the carbon tool steels.

It has been noted when making tests of the chisels that the heat treatment does not extend back far from the cutting edge, and there is only a short distance on the tool where the maximum cutting life can be obtained. If the chisel proved to be brittle on the first test, indicating that the temper had not been drawn sufficiently, in all probability the second test would be more satisfactory, while a third test might show that the chisel was too soft.

The button-rivet set used for the class 4 carbon tool steel is shown on sheets Nos. 1058 and 1521, Plates 142 and 144. The set was heated to the desired temperature and quenched in brine, after which the temper was drawn in a lead bath. Each set drove a certain number of hot rivets, and an observation of its condition was made after the test, but this is not a test to destruction as are the preceding tests, and is, therefore, not so decisive.

GENERAL NOTES.

Earlier in this paper the statement was made that the observations of the elapsed time of run for the selective test of tungsten tool steel, class 1, data for which are shown on sheet No. 1058, Plate 142, were adjusted by the principles of least squares. By referring to that sheet it will be noted that four observations were rejected, and by referring to sheet No. 1520, Plate 143, it will be noted that only one observation was rejected. The terms "residual" and "probable error" used on sheet No. 1058, Plate 142, were changed to "deviation" and "probable deviation" on sheet No. 1520, Plate 143. The observations of the carbon tool steels do not agree as closely as those for tungsten tool steel, class 1, and the causes for the variations are not very easily determined. In the case of the milling cutters the cutting life is considerably reduced if there is very much vibration, and in order to overcome this as much as possible a heavy, rigidly constructed milling machine was used. If the cutters were not exactly central in the arbor so that they did not rotate around their geometric axis, vibrations would be set up which would increase in violence until the cutter finally broke, and it was therefore necessary to fit very carefully the cutters into the arbor.

The pneumatic chisels were operated by a man, which, of course, introduced a greater variation than if a machine were used. The question as to whether or not the test should be stopped, due to the condition of the tool, is sometimes a matter of individual opinion, such as to the degree of dullness, or the amount of reduction in width of cutting edge due to wearing of the sides.

The treating temperature for the tungsten tool steel, class 1, can be varied through a short range in the vicinity of 2,250° F., without producing much variation in the results of the physical test. The treating temperature of the carbon tool steels seems to be within narrower limits, which may perhaps account for some of the variations in the test. It is, of course, extremely difficult to hold the furnaces, which are of the oil-burning type, to absolutely definite temperatures.

The test of the carbon tool steel, classes 1 and 2, which contained tungsten, showed less variation than the carbon tool steels, as may be seen by referring to sheet No. 1521, Plate 144. This may indicate that the addition of tungsten increases the treating temperature limits slightly without affecting the results of the physical test very much. The addition of tungsten seems to produce two desirable results: increasing of the cutting life of the tools and increasing the treating temperature limits of the tool steels. Furthermore, the tool steel containing this element apparently does not require any different method of treating from that in general use for carbon tool steels.

A test was made of tools from Schedule 3244 to determine the relation between the cutting speed and the elapsed time of run, or cutting life of the tool, all conditions being maintained constant except cutting speed. The curve obtained from this test is shown on sketch No. 288, Plate 140.

Photomicrographs have been made of all the tungsten tool steel, class 1, tools used in the selective test for Schedule 4469 by the Naval Experiment Station, Annapolis, Md. Two photomicrographs were taken of the top face of each tool, one near the end where the chip rubbed, which has been marked "A," and the other a short distance back which has been marked "B." The following photomicrographs, shown on Plate 139, were made of tools after the selective test had been completed and the surface from which they were taken is about $\frac{3}{8}$-inch below the surface exposed to the furnace heat:—

Card No. 4, B 2, from tool No. 1–2.
Card No. 8, B 4, from tool No. 2–4.
Card No. 4, B 2, from tool No. 3–2.
Card No. 5, A 3, from tool No. 4–3.

Card No. 6, B 3, from tool No. 1–3, which was re-treated after the selective test had been completed. The top of this tool was ground off and polished for etching. The photomicrographs were made to determine the differences in the structure of the tool steels.

When this navy yard was selected as the purchasing station for tool steels, there was no information on file as to the dimensions or amounts of the several kinds of tool steels which would be needed by the navy yards per annum. Tool steels were, therefore, purchased under the specifications given in Appendix A from time to time as required. This method necessitated advertising for bids at intervals and caused delays in delivering to a navy yard the tool steel it had ordered.

The expense of a selective test as given in Appendices C and D would be prohibitive if it were to be made to determine the award of contract for small quantities of tool steel. It was therefore decided to recommend the purchase of a six-months supply of tool steels in order, to test the specifications given in Appendix C, to reduce to a minimum the ratio of the cost of the selective test to that of the entire amount of tool steel purchased, and to get a stock in store. Schedule 3893 was prepared for this purpose.

The selective test under Schedule 3893 indicated that only minor modifications of the specifications were necessary; and it was therefore considered safe to recommend that an annual contract for tool steels be made. The contract should be so framed that tool steels of any reasonable dimensions and in accordance with the classification of the specifications given in Appendix D, could be ordered in any desired quantities throughout a fiscal year. Schedule 4469 was prepared to meet these requirements, and an extract, which is given in Appendix E, has been made from it to explain the general scheme.

The writer wishes to acknowledge the kind assistance of Mr. Victor Johnson, of the Machinery Division, Philadelphia Navy Yard, and of the representatives of the tool steel manufacturers who observed the forging, treating and testing of the tools during the selective test of tungsten tool steel, class 1, Schedule 4469.

APPENDIX A.*

SPECIFICATIONS (47S5) FOR HIGH-SPEED TOOL STEEL ISSUED BY THE NAVY DEPARTMENT, JANUARY 5, 1909.

1. The steel shall be made by the crucible process, and shall be of uniform quality throughout, and shall be delivered in bars of commercial length, no short bars to be received, and shall be delivered annealed unless otherwise specified. The bars shall be free from all seams, cracks, and other mechanical defects.

2. The steel shall be delivered and inspected in lots of not more than 5,000 pounds, unless otherwise specified, each lot containing its proper proportion of the sizes called for on the requisition.

3. The inspection shall be made at the Navy Yard, League Island, Pa., and shall be under the direction of an officer detailed for that duty by the Commandant of the yard.

4. Each bar, up to and including a sectional area of $2\frac{1}{4}$ square inches, shall be delivered with a test piece on one end about one and one-half times the larger dimension of the bar in length, nicked one-quarter through from each side while bar was hot, so that the test piece may be easily broken off. Larger bars to have coupon test piece forged on one end and nicked as stated above. The test piece must be stamped to match the number of the bar, and when forged down as a coupon must be about 1 inch by $1\frac{1}{2}$ inches and about 3 inches long.

5. The test piece from each bar will be broken off and subjected to a high-heat test in an approved furnace, kept at a definite uniform temperature, which shall be as high as practicable. The test piece, when broken off the end of the bar, should show the fine grain which is characteristic of this class of high-speed tool steel when properly made.

HIGH-HEAT TEST.

6. The test piece shall be preheated slowly and thoroughly in a preheating furnace kept at a uniform temperature of about 1,550° F. When thoroughly heated the test piece shall be quickly transferred to the high-heat furnace and rapidly heated to just below the melting point, then promptly removed from the furnace and blown cold in a heavy blast of air.

*The Appendices A, B, C and D are reproductions of specifications issued by the Navy Department.

7. Each test piece shall then have ground off one end by wet emery grinder an amount at least equal to one-half the thickness of the test piece, leaving the end after grinding a V-shape. This V-end shall then test "file hard." Each bar failing in this test shall be rejected and another bar furnished in its stead by the contractors, and failure of ten per cent of the bars in any lot to meet this test shall reject that lot.

8. Chemical analyses shall be taken and the steel of each lot shall show the following maximum and minimum limits for the elements named:—

	Not less than—	Not more than—
	Per cent.	*Per cent.*
Tungsten	18.50	19.50
Chromium	5.25	6.00
Vanadium	.10	.35
Carbon	.55	.75
Manganese	—	.15
Silicon	—	.110
Phosphorus	—	.020
Sulphur	—	.020

There shall be no other impurities or ingredients, except iron, particularly no molybdenum.

9. From each lot of tool steel one or more tools shall be forged and treated with the standard high-heat treatment and ground to a uniform standard shape of cutting edge for lathe tools; these tools shall be given a standard twenty-minute test on a steel forging of the following chemical and physical characteristics, viz., to be open-hearth, either nickel or carbon steel, annealed:—

Minimum tensile strength, 80,000 pounds.

Minimum elastic limit, 50,000 pounds.

Minimum elongation in 2 inches (cold bend about an inner diameter of 1 inch through 180 degrees), 25 per cent.

Maximum phosphorus, 0.06 per cent.

Maximum sulphur, 0.04 per cent.

The lathe tool, known as the standard $\frac{7}{8}$-inch tool, shall be able to take a cut of $\frac{3}{16}$-inch depth, with $\frac{1}{16}$-inch feed, at surface speed of 60 feet per minute.

Copies of the above specifications can be obtained upon application to the various navy pay officers or to the Bureau of Supplies and Accounts, Navy Department, Washington, D. C.

References: Department's order, dated December 12, 1908; S. and A. 73975.

SPECIFICATIONS FOR CARBON TOOL STEEL.

Grade "A."

Tool steel of this grade is to be used for the following purposes:—Finishing tools, special machine cutting tools, etc. Grade "A" tool steel shall have a chemical composition approximately as follows:—

	Per cent.		*Per cent.*
Carbon	1.10	to	1.25
Silicon	.20	to	.30
Manganese	.20	to	.30
Phosphorus, not more than	.015		
Sulphur, not more than	.015		
Tungsten, as desired, but not to exceed	3.00		
Vanadium, as desired.			

Physical Tests.—Samples submitted shall be made up into a standard $\frac{3}{4}$ by $1\frac{1}{8}$ inch round nose roughing tool, and with a depth of cut of $\frac{3}{16}$ inch, $\frac{1}{16}$ inch feed, shall cut at the rate of 15 feet per minute for 20 minutes without serious injury to the nose of the tool. After redressing and grinding, the cutting speed shall be increased to 30 feet per minute, the depth of cut reduced to $\frac{1}{8}$ inch and feed to $\frac{1}{32}$ inch. The tool shall stand up 20 minutes under this cut. The above test should be carried on a steel cylindrical forging of the same physical character as called for under the high-speed tool steel test above.

Grade "B."

For taps, milling cutters, drills, forming tools, threading tools, threading dies, punches, etc.

Grade "B" tool steel shall have a chemical composition approximately as follows:—

	Per cent.		Per cent.
Carbon	.90	to	1.00
Silicon	.20	to	.25
Manganese	.20	to	.25
Phosphorus, not more than	.020		
Sulphur, not more than	.025		
Vanadium, as desired.			

Physical Test.—End-milling cutter shall be made up from 1-inch selected at random bars and be tested on mild steel, the cut to be $\frac{3}{4}$ of an inch wide and $\frac{1}{16}$ of an inch in depth; at the rate of 85 revolutions per minute the cutter shall travel not less than 30 inches without serious injury to the blade. The second trial shall then be made with the same cut as above at the rate of 150 revolutions per minute. The cutters shall travel at least 15 inches. Hand taps shall be made up from $\frac{1}{2}$ inch bar and tested on $\frac{7}{16}$-inch grade "A" tool steel, oil hardened, and the taps shall thread cleanly at least three holes. Quarter-inch screw dies shall be tested on drill rod steel and at 150 revolutions per minute shall cut 36 inches.

Grade "C."

For chisels, for hot and cold work, rivet punches, die blocks, shear blades, structural work, blacksmith's tools, hand bars, etc.

Grade "C" tool steel shall have a chemical composition approximately as follows:—

	Per cent.
Carbon, not less than	.90
Silicon, not less than	.15
Manganese, not less than	.15
Phosphorus, not more than	.030
Sulphur, not more than	.030

Physical Tests.—Samples submitted under Grade "C" shall be made up into machine chisels, structural steel punches, and flat drills. The chisels (side cutting type) shall be tested on mild steel plates $\frac{3}{4}$ inch thick, the depth of cut to be $\frac{1}{8}$ inch, and the length of cut shall in no case be less than 9 feet. Samples shall be taken at random from the chipping blanks and made up into cape chisels and shall be tested on nickel steel plates 2 inches in thickness and shall cut through the plate for a distance of at least 3 inches without serious injury to the chisel. The structural steel punches, $\frac{3}{8}$ inch in diameter, shall be tested on mild steel plates $\frac{5}{16}$ inch thick, and they shall punch not less than 600 holes at the rate of 60 holes per minute.

The flat drills, 1 inch in size, cutting on $\frac{7}{8}$-inch nickel steel at the rate of 74 revolutions per minute, shall drill at least one hole within a time limit of three minutes.

Determination of carbon in all cases by the combustion method.

All of the above steel shall be made by the crucible process and in each grade shall be of uniform quality throughout, to be straight and true to form and size.

No cutting compounds, water or lubricants are to be used in testing the tools as above, and all tools must be in good condition at the end of the test, and in order to insure acceptance of the lot. Tools of similar type made up from materials submitted by the successful bidder shall be identical in all dimensions.

Deliveries of 30 per cent of each size in each grade of carbon tool steel shall be made within 30 days, and such additional quantities of each size in each grade as may be ordered by the General Storekeeper within 90 days after date of order.

APPENDIX B.

SPECIFICATIONS FOR HIGH-SPEED TOOL STEEL, FOR U. S. NAVAL ACADEMY.

SCHEDULE 3244.

Chemical Composition.

	Not less than—	Not more than—
	Per cent.	*Per cent.*
Tungsten	16.00	20.00
Chromium	3.00	6.00
Carbon	.55	.75
Vanadium	——	1.00
Manganese	——	.20
Silicon	——	.25
Phosphorus	——	.020
Sulphur	——	.020
Iron	Remainder.	

The tool steel shall be made in either the electric or crucible furnace. The bars must be forged accurately to the dimensions specified, free from seams, checks, or other physical defects and be of homogeneous composition. The bars will be delivered in commercial lengths, but bars shorter than 8 feet will not be accepted.

The tool steel shall be delivered in one shipment. Bars will be selected at random from the shipment, forged into test tools and tested as described below. Samples will be taken for chemical analysis. If these test tools do not show results at least equal to the sample bar tools it shall be considered sufficient cause for rejection of the entire shipment, and the contractor shall replace the shipment within two weeks after receipt of notice of rejection.

Tests.—The test tool will have a section of $\frac{3}{4}$ by $1\frac{1}{2}$ inches, and will be forged and ground in the form of the No. 30 lathe tool of the Sellers system of tool forms. Each tool will be tested on a nickel-steel forging of about 100,000 pounds tensile strength, with a cut $\frac{1}{4}$ inch deep, $\frac{1}{16}$ inch feed, and cutting speed of 45 feet per minute. The tool will be twice reground and retested. A record will be made of the length of time the tool cuts before it is ruined. This test may be modified at the discretion of the engineer officer.

Bids.—Prior to the time fixed for opening the bids each bidder must submit a sample bar of the steel he proposes to furnish, to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa.

Samples delivered late will not be received and the bids will not be considered.

The bidder will determine the exact composition for the sample bar, but it must be within the limits specified. If, however, the bidder wishes to submit more than one sample of a composition between the limits specified, provided each bar is of different composition, he may do so. The sample bars must be $\frac{3}{4}$ by $1\frac{1}{2}$ inches section by 6 feet long. Each sample bar will be marked to correspond with the bid. These bars will be forged into 5 tools and tested as specified above.

Each bidder shall inform the Engineer Officer, Navy Yard, Philadelphia, Pa., of the exact chemical composition of the sample bar or bars delivered to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa., and he will state in detail the treatment to which the test tools must be subjected in order to get, in his opinion, the best results. This information will be considered confidential.

All bids and sample bars to be referred to the Engineer Officer, Navy Yard, Philadelphia, Pa., for him to make the tests outlined above and to recommend the award of contract for the steel which, in his opinion, is best suited for the purpose, due consideration begin given to cost.

General.—Bids on tool steel differing from the above chemical composition will be considered, provided the material is suitable for the purpose intended. A statement of the chemical composition as outlined above will be required.

Failure to comply with all requirements will render the bid liable to rejection.

All descriptive matter modifying the above specifications must be in duplicate, labeled with the above class number and pasted or otherwise attached to this page of the proposal in both the original and duplicate bids. Detailed specifications, in duplicate, stating specifically wherein the article proposed does not conform to the above specifications must also be submitted.

APPENDIX C.

SPECIFICATIONS (47S5) FOR TOOL STEEL ISSUED BY THE NAVY DEPARTMENT JULY 20, 1911.

(Superseding "Specifications 47S5," issued January 5, 1909.)

Chemical Composition.

Tungsten steel.	Class 1.	Class 2.
	Per cent limit.	Per cent limit.
Carbon	0.75 to 0.55	1.50 to 1.35
Chromium	5.00 to 2.50	Optional.
Manganese	.30 to .05	.20 to .10
Phosphorus	.015 to .00	.015 to .00
Silicon	.30 to .00	.20 to .00
Sulphur	.02 to .00	.02 to .00
Tungsten	20.00 to 16.00	5.00 to 2.00
Vanadium	.. to .35	Optional.
Iron	Remainder.	Remainder.

Carbon steel.	Class 1.	Class 2.	Class 3.	Class 4.
	Per cent limit.	Per cent limit.	Per cent limit.	Per cent limit.
Carbon	1.25 to 1.15	1.15 to 1.05	0.95 to 0.85	0.85 to 0.75
Chromium	Optional.	Optional.	Optional.	Optional.
Manganese	.35 to .15	.35 to .15	.35 to .15	.35 to .15
Phosphorus	.015 to .00	.015 to .00	.02 to .00	.02 to .00
Silicon	.40 to .10	.40 to .10	.40 to .10	.40 to .10
Sulphur	.02 to .00	.02 to .00	.02 to .00	.025 to .00
Vanadium	Optional.	Optional.	Optional.	Optional.
Iron	Remainder.	Remainder.	Remainder.	Remainder.

1. Method of manufacture and physical requirements.—The tool steel shall be made in either the electric or crucible furnace. The bars must be forged or rolled accurately to the dimensions specified, be free from seams, checks, and other physical defects and be of homogeneous composition. The tungsten steels will be delivered unannealed unless otherwise specified, and the carbon steels will be delivered annealed unless otherwise specified. The bars will be delivered in commercial lengths and short pieces will not be accepted unless so specified.

2. Stamps on material.—The contractor shall stamp on each bar or piece of steel his name, his trade name of the steel which he is furnishing, and the kind of steel and class as given in these specifications. If the bars are longer than about 3 feet the above stamps will be placed at intervals of about 3 feet along the bar.

3. Delivery of material.—All material will be delivered to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa. Lots of material less than 1,000 pounds will be delivered in one shipment, and in general all material will be delivered in one shipment if practicable.

4. Acceptance test.—Samples for acceptance test will be taken from the material delivered to the General Storekeeper, Navy Yard, Philadelphia, Pa., or if the material is inspected at the place of manufacture, the inspector of engineering material will forward samples as called for under the heading "samples furnished by bidder" to the General Storekeeper, Navy Yard, Philadelphia, Pa., who will forward them to the engineer officer. The engineer officer will arrange for the tests, both chemical and physical, required by these specifications and recommend the acceptance or rejection of the material.

5. Rejection.—If the material is not equivalent to the sample furnished with bid it will be considered sufficient cause for rejection. The contractor shall replace the shipment within two weeks, if practicable, after the receipt of notice of rejection.

PHYSICAL TESTS.

Tungsten Steel.

6. Class 1.—The sample bar will be forged into 5 tools, treated and ground to the No. 30 form of the Sellers system of tool forms. Each tool will be tested on nickel-steel forging of about 100,000 pounds tensile strength, with a cut $\frac{1}{4}$ inch deep, $\frac{1}{16}$ inch feed, and a cutting speed of 50 feet per minute. The tool will be twice reground and retested. A record will be made of the length of time the tool cuts without a lubricant or cutting compound before it is ruined.

7. *From the sample bar, $3\frac{3}{8}$ inches round, 2 butt mills, $3\frac{1}{8}$ inches diameter, will be made and tested on a nickel-steel block, with cut 0.20 inch deep, $1\frac{1}{4}$ inches wide, feed 0.04 inch per revolution of mill, at a speed of 100 feet per minute. Each mill to run at least 40 inches and be in fair condition at end of run. Lubricant to be used.

8. Class 2.—The bar will be forged into 5 tools, treated and ground to the No. 22 form of Sellers system of tool forms. Each tool will be tested on a carbon open-hearth steel forging of about 60,000 pounds tensile strength, with a cut $\frac{1}{32}$ inch deep, $\frac{1}{8}$ inch feed, and a cutting speed of about 50 feet per minute. A record will be made of the length of time the tool cuts with a lubricant or cutting compound before it is ruined.

9. *From the $\frac{3}{4}$ by $1\frac{1}{2}$ inch sample bar, 3 standard round-nose roughing tools will be made and tested on nickel-steel forging, with a $\frac{1}{4}$ inch cut; feed 0.05 inch per revolution, and a speed of 15 feet per minute. Each tool should run for 20 minutes without serious injury without a lubricant.

Carbon Steel.

10. Class 1.—Machinists' taps, $\frac{3}{8}$-inch diameter, will be made and tested on nickel steel. A record will be made of the number of holes tapped before the tap is ruined. A lubricant will be used, and the revolutions per minute of the tap will be varied to suit conditions.

11. *From the $2\frac{1}{2}$-inch square sample bar 3 finishing tools will be made and tested on a nickel-steel forging, with a cut from 0.001 to 0.003 inch deep, a feed $2\frac{1}{4}$ inches per revolution, and a speed of 8 feet per minute. Each tool should make a clean, smooth finish for a run of at least 20 feet without lubrication.

12. Class 2.—One 1-inch end mill will be made and tested with a lubricant by cutting a piece of class 4 carbon steel. The depth of cut will be $\frac{1}{16}$ inch, the revolutions per minute will be varied to suit conditions, and a record will be made of the length of time the mill cuts before it is ruined.

13. *From the sample bar, $1\frac{3}{8}$ inches round, one end mill, $1\frac{1}{4}$ inches diameter, will be made and tested on a mild-steel block, cut 0.20 inch deep, 0.50 inch wide; feed 0.018 inch per revolution; at a speed of 40 feet per minute. The mill should run at least 40 inches and be in fair condition at the end of run. Lubricant to be used.

14. Class 3.—Pneumatic cape chisels, $\frac{1}{2}$-inch, will be made and tested with a lubricant on nickel steel. A record will be made of the distance the tool cuts before it is ruined.

15. Class 4.—Rivet sets, $\frac{1}{2}$-inch, will be made and tested, and a record will be made of the number of rivets the set will drive before it is ruined.

16. Modification of tests.—Any or all the above tests may be modified at the discretion of the engineer officer.

17. Samples furnished by bidders.—Each bidder shall furnish with his bid one bar of steel as follows:—

Tungsten—

Class 1.—$\frac{3}{4}$ by $1\frac{1}{2}$ inches by 5 feet long.
*Class 1.—$3\frac{3}{8}$ inches round by 24 inches long.
Class 2.—$\frac{3}{4}$ by $1\frac{1}{2}$ inches by 5 feet long

Carbon—

Class 1.—$\frac{1}{2}$-inch diameter rod, 2 feet long.
*Class 1.—$2\frac{1}{2}$ inches square by 6 feet long.
Class 2.—$1\frac{1}{4}$-inch diameter rod, 2 feet long.
*Class 2.—$1\frac{3}{8}$ inches round, 24 inches long.
Class 3.—$\frac{3}{4}$-inch octagon rod, 5 feet long.
Class 4.—2-inch diameter rod, 2 feet long.

18. All samples must be delivered (unless otherwise specified in the proposal) to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa., prior to the time fixed for opening the bids. Failure to comply with this requirement will eliminate the bid from consideration. The sample bar will be delivered by the general storekeeper to the engineer officer for him to direct the selective tests.

Samples delivered late will not be received and the bids will not be considered.

19. *The requirements indicated by asterisk apply only to tool steel required for delivery to the Navy Yard, Washington, D. C.

20. Treatment of samples.—Each bidder must state in his bid the treatment to which the material is to be subjected in order to get, in his opinion, the best results.

21. Recommendation of award.—The right is reserved to reject any or all bids. Failure to comply with all the requirements will eliminate the bid from consideration.

22. The engineer officer will, after the prescribed tests have been made, recommend the award for contract for the steel or steels which, in his opinion, it is to the best interest of the government to purchase, due consideration being given to the cost of the material. The relation of the physical test and the price of the material will be the basis for selection.

23. Alternate proposals.—Bidders may submit proposals on steel which differs from the composition specified, provided this is clearly stated in their bids, and provided they furnish the engineer officer with the exact chemical composition of the material. This information will be considered confi-

dential by the engineer officer if the bidder request it. The material will be tested if, in the opinion of the engineer officer, it is considered suitable for the purpose intended.

24. Defective material.—If material, when being manufactured into tools, develops physical defects which could not be detected by inspection, such as "cracks," "pipes," etc., the manufacturer of this steel shall replace, without cost to the government, such defective material.

PURPOSE FOR WHICH THE STEEL IS INTENDED.

Tungsten Steel.

25. Class 1.—Lathe and planer tools, milling-machine tools, etc., and in general all tools for which high-speed steel is used.

26. Class 2.—Lathe and planer tools, and in general tools for finishing purposes, either steel or brass.

Carbon Steel.

27. Class 1.—Lathe and planer tools, drills, taps, reamers, screw-cutting dies, taps, and tools requiring keen cutting edge combined with great hardness.

28. Class 2.—Milling cutters, mandrels, trimmer dies, threading dies, and general machine-shop tools requiring a keen cutting edge combined with hardness.

29. Class 3.—Pneumatic chisels, punches, shear blades, etc., and in general tools requiring hard surface with considerable tenacity.

30. Class 4.—Rivet sets, hammers, cupping tools, smith tools, hot drop forge dies, etc., and in general tools which require great toughness combined with the necessary hardness.

Copies of the above specifications can be obtained upon application to the various navy pay officers or to the Bureau of Supplies and Accounts, Navy Department, Washington, D. C.

References: Department's order, Dec. 12, 1908; Tool Steel Board, June 7, 1911; Dept., 25164–200f., June 8, 1911; Bu. C. and R., 2328-A. 104, June 13, 1911; S. and A., 73975, 85744, and 104054.

APPENDIX D.

Specifications for Schedule 4469.

PURPOSE FOR WHICH THE STEEL IS INTENDED.

Tungsten Tool Steel.

1. Class 1.—Lathe and planer tools, milling-machine tools, and in general all tools for which high-speed steel is used.

Carbon Tool Steel.

2. Class 1.—Lathe and planer tools, and tolls requiring keen cutting edge combined with great hardness, for finishing shrinkage dimensions on nickel-steel gun forgings, drills, taps, reamers, and screw-cutting dies.

3. Class 2.—Milling cutters, mandrels, trimmer dies, threading dies, and general machine-shop tools requiring a keen cutting edge combined with hardness.

4. Class 3.—Pneumatic chisels, punches, shear blades, etc., and in general tools requiring hard surface with considerable tenacity.

5. Class 4.—Rivet sets, hammers, cupping tools, smith tools, hot drop forge dies, etc., and in general tools which require great toughness combined with the necessary hardness.

Chemical Composition.

Tungsten tool steel.	Class 1, per cent limit.	
	Maximum.	Minimum.
Carbon	0.75	0.55
Chromium	5.00	2.50
Manganese	.30	.05
Phosphorus	.015	.00
Silicon	.30	.00
Sulphur	.02	.00
Tungsten	20.00	16.00
Vanadium	1.50	.35
Iron	*	*

*Remainder.

Carbon tool steel.	Class 1, per cent limit.		Class 2, per cent limit.		Class 3, per cent limit.		Class 4, per cent limit.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
Carbon	1.25	1.15	1.15	1.05	0.95	0.85	0.85	0.75
Chromium	†	†	†	†	†	†	†	†
Manganese	.35	.15	.35	.15	.35	.15	.35	.15
Phosphorus	.015	.00	.015	.00	.02	.00	.02	.00
Silicon	.40	.10	.40	.10	.40	.10	.40	.10
Sulphur	.02	.00	.02	.00	.02	.00	.025	.00
Vanadium	†	†	†	†	†	†	†	†
Iron	*	*	*	*	*	*	*	*

*Remainder. †Optional.

PHYSICAL TESTS.

Tungsten Tool Steel.

6. Class 1.—The sample bar will be forged into 5 tools, treated and ground to the No. 30 form of the Sellers system of lathe tool forms. Each tool will be tested on a nickel-steel forging of about 100,000 pounds tensile strength, with a cut $\frac{1}{4}$ inch deep, $\frac{1}{16}$ inch feed, and a cutting speed of 50 feet per minute. Each tool will be twice reground and retested. A record will be made of the length of time each tool cuts without a lubricant or cutting compound before it is ruined.

Carbon Tool Steel.

7. Class 1.—Five $\frac{7}{16}$-inch diameter, 4-tooth facing mills will be made from the sample bar and tested on a piece of $\frac{5}{8}$-inch ship's plate without lubricant. Each mill will be run until it is so dull that it breaks either in the teeth or in the shank. The depth of cut will be 0.08 inch, the revolutions per minute of the mill will be 370, and the feed of material 20 inches per minute. A record will be made of the length of time each mill operates.

8. Class 2.—Five $\frac{7}{16}$-inch diameter, 4-tooth facing mills will be made from the sample bar and tested on a piece of $\frac{5}{8}$-inch ship's plate without lubricant. Each mill will be run until it is so dull that it breaks either in the teeth or in the shank. The depth of cut will be 0.08 inch, the revolutions per minute of the mill will be 370, and the feed of material 20 inches per minute. A record will be made of the length of time each mill operates.

9. Class 3.—Five $\frac{1}{2}$-inch pneumatic chisels will be made from the sample bar. Each chisel will be tested on a nickel-steel plate with a cut $\frac{1}{16}$ inch deep.

A record will be made of the distance each chisel cuts with a lubricant before it is ruined.

10. Class 4.—Two $\frac{1}{2}$-inch rivet sets will be made from the sample bar. A record will be made of the condition of the sets after a certain number of rivets have been driven.

11. Modification of tests.—Any or all of the above tests may be modified at the discretion of the engineer officer.

General.

12. Method of manufacture.—The tool steels shall be made in either the electric or crucible furnace. The bars must be forged or rolled accurately to the dimensions specified, free from seams, checks, and other physical defects and of homogeneous composition. The tungsten tool steels shall be delivered unannealed, unless otherwise specified, and the carbon tool steels shall be delivered annealed unless otherwise specified. The bars shall be delivered in commercial lengths and short pieces will not be accepted unless so specified.

13. Stamps on material.—Each bar or piece of tool steel, whether sample bar for "selective test," "acceptance test," or material delivered under contract, shall be stamped with the manufacturer's name, his trade name and temper index, and in addition identification stamps of the kind and class of tool steel as given in these specifications. The tungsten tool steel, class 1, shall be stamped T–1, and the carbon tool steels, classes 1, 2, 3, and 4: C–1, C–2, C–3, and C–4. The letters to be about $\frac{3}{16}$ inch high. If the bars are longer than about 4 feet, the above stamps should be placed at intervals of about 3 feet along the bar.

14. Acceptance test.—Sample bars for "acceptance test" will be taken from the material delivered under contract to the General Storekeeper, Navy Yard, Philadelphia, Pa., or if the material is inspected at the place of manufacture, the inspector will forward sample bars of the dimensions called for to the General Storekeeper, Navy Yard, Philadelphia, Pa., who will forward them to the engineer officer for him to arrange the tests indicated by these specifications and recommend the acceptance or rejection of the material. If the material proves to be not equivalent to the sample bar furnished with proposal this will be considered sufficient cause for rejection. The contractor shall replace the shipment within two weeks, if practicable,

after the receipt of notice of rejection. The sample bars used for this test will be credited the contractor if the material under test is accepted.

15. Defective material.—If material, when being manufactured into tools, develops physical defects which could not be detected by inspection, such as "cracks," "pipes," etc., the manufacturer of this steel shall replace, without cost to the government, such defective material.

Proposals.

16. Reservation and alternate proposals.—The right is reserved to reject any or all proposals.

Bidders may submit proposals on tool steel which differs from the composition and method of manufacture specified, provided this is clearly stated in their proposal, and provided they furnish the engineer officer with a statement of the exact chemical composition and method of manufacture of the tool steel. This information will be considered confidential by the engineer officer if the bidder requests it. The tool steel will be tested if, in the opinion of the engineer officer, it is considered suitable for the purpose intended.

17. The engineer officer will, after the prescribed tests have been made, recommend the award of contract for the steel or steels which, in his opinion, it is to the best interest of the government to purchase, due consideration being given to the cost of the material. The relation of the tests and the price of the material will be the basis for selection.

18. Selective test.—Each bidder shall furnish with his proposal a sample bar of tool steel stamped as called for under heading "Stamps on material" for the "selective test." The relation of the results obtained from the tests conducted as provided for under the heading "Physical tests" and the price of the material determine the selective factor. The dimensions of the sample bars shall be as follows:—

Tungsten tool steel—

Class 1.—$\frac{3}{4}$ by $1\frac{1}{2}$ inches by 5 feet long.

Carbon tool steel—

Class 1.—$\frac{5}{8}$-inch diameter rod, 2 feet long.

Class 2.—$\frac{5}{8}$-inch diameter rod, 2 feet long.

Class 3.—$\frac{3}{4}$-inch octagon rod, 5 feet long.

Class 4.—2-inch diameter rod, 2 feet long.

19. Treatment of samples.—Each bidder will state in his proposal, if he considers it necessary to do so, the treatment to which the material must be subjected in order to get, in his opinion, the best results.

20. Delivery of sample bars.—All sample bars stamped as called for under the heading "Stamps on material" must be delivered to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa., prior to the time fixed for opening of proposals. Sample bars delivered late will not be received. Failure to comply with the above requirements will eliminate the proposal from consideration. All sample bars will be delivered by the general storekeeper to the engineer officer for him to conduct the "selective tests."

APPENDIX E.

Extract from Schedule 4469.

No. of item.	Articles.	Unit price.		Total.	
		Dollars.	Cents.	Dollars.	Cents.
	CLASS 21.—(Request No. 229, G. A. A., Naval Supply Account, C. and R. and S. E.—Philadelphia, Pa.—Sch. 4469.)				
	To be delivered at the navy yard, Philadelphia, Pa., during the fiscal year ending June 30, 1913, as may be required (no single order to be for less than 1,000 pounds, except with the consent of the contractor), within 30 days after date of receipt of order from the general storekeeper. If unable to make delivery within the time specified, state actual number of days required, bureau reserving right to make award on time stated above.				
	STOCK CLASSIFICATION NO. 46.				
	Tungsten tool steel, class 1, round, square, octagon, or hexagon, as may be required, as follows:				
	Annealed—				
1	200 pounds (about) $\frac{5}{8}$ to 2 inches, inclusive.....per pound	.....	.....	.....	.....
2	100 pounds (about) $2\frac{1}{8}$ to 3 inches, inclusive.....per pound	.....	.....	.....	.....
3	100 pounds (about) $3\frac{1}{8}$ to 4 inches, inclusive.....per pound	.....	.....	.....	.....
*	* * * * * * * *	.....	.....	.....	.....
99	100 pounds (about) $3\frac{1}{3}$ to 4 by $6\frac{1}{8}$ to 8 inches, inclusive....per pound	.....	.....	.....	.....
100	100 pounds (about) $4\frac{1}{8}$ to 5 by $4\frac{1}{8}$ to 7 inches, inclusive ...per pound	.....	.....	.....	.....
101	100 pounds (about) $4\frac{1}{8}$ to 5 by $7\frac{1}{8}$ to 8 inches, inclusive....per pound	.....	.....	.....	.....
102	100 pounds (about) $5\frac{1}{8}$ to 6 by $5\frac{1}{8}$ to 8 inches, inclusive....per pound	.....	.....	.....	.....
103	100 pounds (about) $6\frac{1}{8}$ to 7 by $6\frac{1}{8}$ to 7 inches, inclusive....per pound	.....	.....	.....	.....
104	100 pounds (about) $6\frac{1}{8}$ to 8 by $7\frac{1}{8}$ to 8 inches, inclusive....per pound	.....	.....	.....	.....
	Intermediate sizes not specified, when required, will be ordered and paid for at the price of the next higher size. For specification, see page 1 of this schedule. (Appendix D.) As the bureau is unable to state definitely the exact quantities of the above material that will be used, the quantities stated above for each item are estimated only and are merely for the information of bidders in preparing bids. It shall be distinctly understood and agreed that it is the intention of the contract that the contractor shall furnish and deliver any quantities of all the above-mentioned material which may be needed for the naval service at the place named during the fiscal year ending June 30, 1913, irrespective of the estimated quantity for each item named above. All bids to be referred to the department.				
	Total Class 21.....	.....	.....	.....	.....

DISCUSSION.

THE CHAIRMAN:—Is there any discussion on this paper presented by Mr. Kenney? I am sure we are all grateful to Mr. Kenney for his trouble in giving us such useful information and that you will permit the chairman to offer him the thanks of the Society.

Now, gentlemen, we have come to the conclusion of one of our most successful meetings. We hope, most of us, to meet together again at seven o'clock at the Waldorf-Astoria. There now remains for the Chair nothing to do but to thank you on behalf of the authors for your appreciative attention to their papers, and to thank the authors for their earnest labor in preparing such valuable contributions for the Society, and to congratulate every one on participating in such an eminently satisfactory meeting. Such a successful meeting, however, cannot be had except through the constant and unremitting labor of our official colleagues, and among those there is none who deserves greater credit and to whom your thanks are due in greater measure than the hard-working Secretary. Before adjourning, therefore, I ask you to give a vote of appreciation and thanks to the Secretary for all he has done in giving us such an excellent program for this meeting. (Loud applause.)

The Twentieth General Meeting of the Society is now adjourned *sine die*.

ADDRESS OF

HON. WILLIAM C. REDFIELD

MEMBER OF CONGRESS FROM NEW YORK

AT THE BANQUET OF

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

NOVEMBER 22, 1912

ADDRESS OF HON. WILLIAM C. REDFIELD.

In speaking to this body of experts I have in mind, that "fools rush in where angels fear to tread," and that a layman might perhaps wisely be silent in the presence of professionals. The excuse, however, is that through the courtesy of your president I was asked to come. The subject was chosen as one of growing interest about which one may humbly venture to suggest there are certain things that ought to be said. Yet I disavow the thought of informing, much less of instructing, those who are wiser. It is merely the difference in viewpoint that leads to the hope that something may be said that will be suggestive and that your greater wisdom will permit you to use or to modify, or to nullify as it may deserve.

An interest in the subject is normal to one whose family for many generations have been shipmasters, naval engineers, or vessel owners, and who has added travel in many seas on vessels under many flags, during which he has used his eyes so far as years of industrial life has taught. I prize as a choice possession an old liqueur bottle which once belonged to the captain of an English brig captured by an American privateer in 1777, and which fell as a share of the prize to the cabin boy of the Yankee vessel who was my great-great-grandfather.

It has been my privilege for twenty years to furnish articles for naval use, and to reckon as valued friends shipbuilders, owners, naval constructors, and engineers and other officers, both of the merchant and war marine of this and other countries. This and a quarter century of manufacturing in machinery lines is the background of my thought, and it is only suggested for that purpose.

You will agree that in studying any important subject it is first necessary to get all the facts and to weigh them justly.

You will agree also that we cannot, if our judgment is to have value, deal only with a part of the facts, and you will also concur that tendencies are facts as truly as are things which have already been accomplished. In

my business and in yours the drift of events is one of the serious things, and it cannot be taken as of to-day or yesterday, but must, as we do in life insurance, be taken in the large and over periods of time in order to judge it accurately. Does it surprise you, therefore, to learn that in reading the transactions of your society for 1909, and the discussion upon the subject of this address, which is therein, the impression was left upon my mind of assumptions that are incomplete and of omissions that are important, while certain statements have already been outgrown? It is particularly the things which are left unsaid that strike me forcibly, and with these the treating of facts as if they were permanent instead of being mere phases in evolution. May I add before discussing this that much of our theme has to do with well-known elements of commercial and industrial life—such as the problems of handling materials, or those of the employment of labor, or the use of tools, or the adjustment of burden charges, or the relation of wage to output. The essential principles of cost are not, I venture to think, different in operating a ship from those which exist in operating a factory. The application and the elements are not the same, but the principles are alike.

What, then, are the major facts which affect to-day the subject of our discussion? One is that the future of our merchant marine is still considered by most Americans a matter of local interest, in which shipbuilders and shipowners, with their employees, have a predominant interest. It is true that in our ports and along our coast states there is an awakening public opinion upon the importance of this subject, but in our inland states and among the great masses of our people there is apathy. I agree with him who once said to you, that when this country realizes that it is a national necessity that ships built in our own yards, officered and manned by our own citizens, owned and operated by our men of affairs, shall represent us in all ports of the world, there will be found a way to do it with profit to all concerned.

It seems probable that the demands for national subsidies to sustain a business which otherwise could not sustain itself, coupled with the fact that sufficiently clear explanation has not been given to the people of our interior states of the ill effects upon us all of the lack of a merchant marine, accounts for much of this indifference. Men in the Central West hearing me speak in favor of a merchant marine have accused me from that simple fact of

wishing to secure it by subsidies, which is far from the case. The two are mingled in the thought of many, if not most, of our people. They should be detached and each proposition should stand upon its own merits. Quite apart from the question of our earning for Americans the hundreds of millions annually paid for transporting our goods, stands the larger fact that we, the greatest of the world's producing nations, cannot long tolerate the thought that the control of our seaborne traffic shall rest with our commercial competitors. Let it once be brought home to our people at large that the grain of the Northwest, the cotton of the Southwest, the steel of Pennsylvania, the manufactures of all our states, which are now sold abroad in increasing volumes and which we must continue to sell to keep our farms and factories going, enter into the control at our water fronts of those whose chief interest it is to limit our export sales and substitute their own, and public opinion will be very different.

So long as it is thought merely to be a matter of who collects the freight our people will not care; serious as it is to have the price of transportation paid outside, but when it comes home that transport of our factory products is in the hands of those whose interest it is to have the products of their own factories sold instead of ours and will so arrange if they can, and that our planters' cotton is also in competing hands, things will be different. We need not go into details of the ill effects of this adverse control. The foreign ships carry our manufactures and grain on such terms as suit them. It is the interest of Americans to have these carried on such terms as suit us. The foreign lines want our business indeed, but in their schedules, their management, their plants, they must prefer their own nationals. It is inconceivable that they should not do so. A German line ought not to operate its American trade in a way hostile to German interests and could not long do so. No more could an English line. They must so treat our American trade that it shall not collide with their own interests, and when the collision occurs their own interests must be preferred. They can combine against us if they will and as in a measure they have. It comes back to the word "control." We are in the hands of our competitors to conduct a business which it is vital to us should be carried on in our interest. This is a bigger question than the building of ships and the making of profits by them—that is personal, but the question is national. That is relatively little,

but the question is nationally large. What prevails in New England to-day but wrath, because that section has failed to be able to control its own transit facilities? They are in the hands of those who are considered alien to the territory, whose interest may or may not lie in developing it as its people wish to have it developed. Boston is objecting to what is in its view a foreign control of its traffic. It is in a small way what we face in our international trade.

But there have been changes in this international trade, because of which the subject takes on more pressing interest. In the discussion before you of 1909 it was suggested that our "export trade cannot be attributed to our skill as manufacturers." This is no longer true. To-day the largest single item in our exports is manufactured and partly manufactured goods, and these have become nearly or quite half of our total exports. If we include among them manufactured food products such as flour, which are, of course, as truly manufactured as are other articles, then our manufactured goods represent more than half. In any case our food products, of which we used to be the world's vendors, have sunk to a minor relative place. It is true now that many American factories could not run full time without their foreign trade. Some factories here sell most of their products abroad. These exports of manufactures will exceed eleven hundred millions in value this year—equal to two-thirds of our total exports of three years ago. The facts of our foreign trade for the month of October just past are even more striking, for in that month our total international trade exceeded four hundred and thirty-two millions, or at the rate greatly in excess of five thousand millions per year. From these startling facts much hope may be drawn for: First, the value of our seaborne traffic is impressing itself upon more of our people. It is coming to have a greater money value to more of us. Second, it has destroyed certain myths, which are some of the assumptions of which we have spoken. The destruction of these myths forms the third group of facts for us to consider.

It is no longer true that goods made in America always cost more because of the higher rate of wages paid here. Go around the world with an open eye to-day and this old tradition will fall before the fact that in every city American goods are freely sold, either because we manufacturers are charitably bestowing them upon the foreigners or because they cost less for the

foreigners to buy or because they are of better quality. The business houses grouped in the American Manufacturers' Export Association, over which I have the honor to preside, do a regular foreign trade in their goods of approximately two hundred millions, and among us it would be rather amusing were one to say that we could not compete because of our wages when as a matter of fact we are doing it all the time. The old belief that the product of a man whose pay was $3 must cost more than the product of a man whose pay was but $2 dies rather hard, but if ever there was a pernicious falsehood this is it.

I had in my hands a few days since a list of 177 different lines of American manufactures in which a good and growing trade is done abroad. American shoes are sold in every European country; so are American tools; American clothing is sold in London, American cotton in India and China. American machinery runs European plants; American machinery operates in the Far East. Talk with German and English manufacturers in their candid moments and you may be surprised at their views. They know, and there are times when they will say, that America is fast becoming their most threatening competitor in the markets of Europe.

Three great facts therefore exist:

First, the need for a keen appreciation of the national value of a merchant marine.

Second, the growth of this appreciation, because of the enormous expansion of our foreign trade and its changing character.

Third, a remarkable change in the competing power of America, which is advancing by rapid steps.

The last two of these three great facts did not exist twenty years ago and even ten years ago were not potent, but now they are rapidly becoming the controlling factors.

A fourth great fact affecting our study is the opening of the Panama Canal. I confess to believing that the effect of this upon the world's commerce will be greater than the most hopeful figures state. For to my mind it means that as a resistant to navigation the American Continent is removed, while as an incentive to navigation it may almost be said that a portion of the American Continent is created. I believe there will come to be round the world lines, not going from hither to yon and back, but continuing around

the globe. Anyhow, the moving of the west coast of South America some thousands of miles nearer our eastern coast, and the possibility of quick, direct water intercourse between our eastern and western coasts is itself sufficient to stimulate our ocean-borne traffic, both coastwise and otherwise, and I venture to think that this effect is already apparent.

A fifth fact bearing directly upon this problem is the growth in efficiency of our own shipbuilding plants. If I am correctly informed, a battleship of, say, 28,000 tons, is now constructed in thirty-three months as compared with one of 14,000 tons in forty-eight months twenty years ago. Admit that the progress is not all to be desired in comparison with work done elsewhere, still it is marked progress. Nor is there any reason to suppose that the advance has reached its limit.

The American yards of ten years hence will be far more effective than those of to-day. This growth in efficiency, however, has been held back and is to-day delayed by a conservatism which takes its lessons from the past of doubt instead of looking toward the future of hope. There are weaknesses existing in our shipbuilding plants which keen self-analysis, frank searching of our own methods to see if they are right, would disclose and remove. There has been, as there has been among our manufacturers, a prevailing unbelief in their own power to compete which has held back the growth of ability to compete. Few things are more expensive than unbelief. A mine superintendent in Pennsylvania allowed a modern fan to lie six months unused because it was so much smaller than its predecessor that he did not believe it would work. A shipyard engineer refused for two years even to have submitted to him apparatus that the navies and merchant marine of European nations had in regular service. The chief engineer of a steamship company had to die before the line was allowed to take advantage of modern apparatus. Are not ships to-day rather too much the result of the searching by draftsmen among old drawings than the deliberate planning of wise and free-minded progressive designing engineers? Just as the shadow of the day when we could not compete with Europe still so projects itself over many of our factories that they do not now know they can compete, so in a measure the inability of the past in our shipyards still acts as a bar on progress in many a plant in this country. What we did or do is no sure measure of what can be done.

In six prosperous concerns in one industry, all paying dividends, the best was running at but 78 per cent of a fair and normal efficiency, and the worst, though also prosperous, was running at but 30 per cent, and none of them knew it. It would be very interesting, to say the least, if in some great yard a man were set and backed by the owners whose duty it was to criticize thoroughly and with care and sober judgment, but still to criticize without mercy and without adhering to tradition, all that went on. In the factory with which I was connected, and with whose shop management I had nothing to do, I did this for many years and never found a day in which something could not be bettered. I have a friend, who is the manager of a great transportation business, who for twenty-five years has had this habit; and while his plant has been of the best, he has never found the time yet when searching examination of it would not make things go better. It is not derogatory to the high character and alert brains of our shipbuilding establishments to believe that that which is true of every industrial plant is also true of them.

Having said this much, it becomes necessary to say more. Our industrial success has not been found in following European lines, but in departing from them. In a new country with high wages the problem has been to make these wages represent efficiency. This has been done even while many cried that they could not do it, and it has been worked out successfully. So there are men that say that American shipyards cannot build as cheaply as foreign ones because of the wage rate. If you change the phrase to "do not," I will in part agree—only in part—because the best marine authority tells me that up-to-date battleships per ton have not cost quite so much in the United States as in England, and because the head of one of our largest shipyards told me himself he could build battleships in competition with any yard in Europe.

I repeat, the progress of American industry has been in following its own individual lines and not the methods of imitation. Those of our industries who have stepped out on new paths have succeeded. Those that have attempted to meet Europe at its own game have found their course rough. Are there not facts to-day in addition to those cited which, if fairly weighed, throw a further light of hope upon our problem?

We used in our shop often to speak of the great difference between making and manufacturing. Anybody can make a thing at some cost or other, but it takes specialized plants and applied brains to manufacture. Now, our shipyards have, in the very nature of things, been obliged too much to "make" ships and have had too little opportunity to "manufacture" them. They have conducted a manufacturing retail business instead of a manufacturing wholesale one, and it is not to be expected that they can reach the highest efficiency so long as this continues. It is therefore to be hoped that the vast increase of our foreign trade and the coming of the Panama Canal, together with our growth of competing power, will make it possible in the near future for something like definite manufacturing of ships to take place. That our yards have developed greatly in efficiency in spite of this retail nature of their trade is to their credit. Yet have they always been as keenly appreciative of what the real advantages of standardization are as they might have been, or has the retail past rather too much overshadowed them when the wholesale was present?

A yard upon the Lakes took five ships, all alike, away from our coast yards at a lower price. Then it took five more, and the cost of the second five was quite a little less than that of the first five, as it ought to have been; and now there are five more proposed, and the cost of the third five will be still less, for we have now a real case of manufacturing. Furthermore, I am told by those who are in position to know that these last five come in cost measurably near to the Glasgow price before the latter advanced to its present high figure.

There is beginning, then, to be a call for numbers of ships sufficient to manufacture them and to put the business of building them on a wholesale instead of a retail basis. A case in point is the fleet of steam barges which has also been ordered from Lake yards for southern use and the tank vessels now building there. There can be no question that the development of this phase of our industry will mean a great increase in competing power over the advance that has already taken place. A year ago we took in London in competition with England fourteen small steamers for the Amazon. I am told more are coming.

It is a fact, too, to-day that material costs less in America than it does abroad. I have here an advertisement of American ship plates in the Far

East. It is also a fact that the price of material and of shipping is very much higher abroad than it has been for long. An English company on the Lakes, which has had its ships built abroad, is now having two built in Canada because of the high foreign price. Possibly this condition may be temporary, but the fact that it is here shows its possibility beyond all doubt and should be a stimulus for those to whom it is an advantage. Given the progress already made while our shipbuilding work was done at retail, for which our builders are to be highly commended; add to it the greater progress that may come from standardized ships, for which four important orders are already under way, as we have seen; given the fact that steel costs less to make here than it does abroad, of which fact there should be no doubt—nor as to its continuance, when we are exporting two hundred and fifty million dollars' worth of steel each year—there is room, in my judgment as a manufacturer, for the belief that, with the normal allowance of time necessary for such a development, we shall build ships here as cheaply as anywhere. I think it is reasonable to expect this—not to-day, but in the near future—as a normal evolution out of past and present facts.

But now arises the bogey of operating cost, and we are told that the cost of wages paid on American ships is such as to prohibit their use in seaborne traffic. Here again, if we are told it does so prohibit, that is a fact we may accept, but it is a very different thing to say therefore it need so prohibit. If five years ago we could not make engines cheaply enough to sell them abroad, that was no reason for believing we never could do so. We do it now, and I may be permitted to point out that the ratio of wages to cost is not a fixed but a flexible fact. It is large or small in proportion to the output. There are no elements here that do not apply in manufacturing. A man at $4 per day, if he be properly equipped, produces goods more cheaply far than a man at $2 a day who has not the means of efficiency, and the latter, if he becomes efficient, speedily rises in his wage rate but not in the cost of his products. Whether, therefore, the wage rate of running an American ship is to be controlling or not depends upon other matters besides the wage rate—namely, upon the output you get in the goods the ship produces—that is, transportation. I believe it is true that one of the lowest, if not the lowest, freight rate in the world is in American ships with highly paid labor.

Ore is carried on the Great Lakes at the rate of .05 of a cent per ton-mile,

which includes all elements of cost and the profit. I have been furnished the details of cost for a Lake ore carrier with a cargo capacity of 6,600 tons. Labor is not the largest element of expense, even when the captain's salary is reckoned for the full year, though the ship is idle four months. The items of depreciation, based upon wiping out the investment in twenty years of insurance premiums, and of handling cargo at terminals, are all of them greater than the wages. Reckoning every element of cost, it appears that wages are but $14\frac{1}{2}$ per cent of the total cost and that the labor cost per ton-mile is less than .011 of a cent. It also appears that a reduction in wages of 25 per cent would reduce the cost of operation less than $3\frac{3}{4}$ per cent.

So, too, I venture to think that in a ship like the Hendrick Hudson on our North River, if she be reckoned as carrying 4,000 passengers, which is 1,000 less than she is licensed to carry, it is probably that the labor cost per passenger-mile is as low as that of like service anywhere in the world. The answer to these facts is that these are specialized ships existing under peculiar conditions which cannot be duplicated. It is true they are specialized ships. The whole progress of American industries has been one of specializing. That is the respect in which it is different from the foreign methods, and the point made here and which I wish to emphasize is that men with open minds and departing from tradition have devised and operate a ship on special lines for special work. The result in shipbuilding and ship operating has been in America just what it has been on other American industries —namely, the reduction of the cost to one of the lowest points known, if not actually the lowest point known. Just as this fact is a pointer to us in our factory dealing with the line of progress, so I venture to think it is a finger that points the way for our marine generally.

But we are told again that conditions are not the same. Certainly they are not, but to some degree they may be similar, and how far have we gone elsewhere toward meeting them? It is an ordinary truth in a factory, as it is in your machine shops, that a tool to be efficient must be kept operating the largest possible percentage of the working day. You do this, of course, but it is not done with the ships when you have built them and they are put in operation. You equip your plants with handling apparatus because you have learned that one of the great losses in industry is the cost of handling goods unnecessarily, but your ship, which is after all an apparatus to

produce transportation, is not so equipped or so handled. Here, too, the men of the Great Lakes have gone ahead. A vessel last week had 11,000 tons of ore taken from her in 3 hours and 15 minutes. Another ship entered Duluth with a cargo in the morning and left at 1.30 p. m. with a fresh cargo of 376,000 bushels of wheat.

It would be interesting to compare the ore rates from Bilbao to the Rhine or from Cuba to the United States with those existing on the Great Lakes, and to analyze the reasons for such differences as may appear.

Come back to our ship when she is put in operation. Is she as a matter of fact the result of an exhaustive study, not only by shipbuilders but by men whose duty it is to handle materials, of the cheapest and most efficient way in which her cargo can be loaded and unloaded, or is she a traditional ship representing a compromise between the elements of the visions of the owner, the views of a steward and the like? She is a tool for carrying freight. I am not speaking of passenger ships. Is she deliberately made the most economical tool that brains can devise for getting that freight into her and out of her? To a man of factory experience the waste of handling freight upon any of our docks seems ruinous. If engineers inform me correctly, it often costs double per ton of package freight merely to get that freight from car to ship in our ports what it does to carry a ton of ore a thousand miles upon the Lakes. Is not the efficiency of your ship, her ability to earn and to carry herself, a problem which has two leading elements in it—namely, the amount of cargo she can transport relatively to her pay roll and other expenses, and the speed and economy with which she can get that cargo into her and out of her?

It would be instructive if a first-class ship designer, freed from the past, would try, as a matter of professional practice, to see what was actually possible in the way of a specialized ship to carry cotton or sugar. There are the equivalent of eighty cargoes of 10,000 tons each of cotton going from Galveston each year, and about forty more of like size each from Savannah and New Orleans. The railroads that carry this cotton to the water front have specialized upon it in the sense that all American railroads have specialized—namely, by larger car capacity, longer trains, heavier engines and rails—the result of which has been to make American railway costs the lowest in the world. But there is none of this specializing when you get to

the dock. Is there not some hope that the same thought which has made the American railroad so efficient and has made the American lake steamer so efficient and the American factory so efficient might devise an American steamship that would also be efficient? And if to such a specialized steamer you can add specialized loading apparatus that would measurably approach the results upon our Great Lakes, would not the vessels that had these advantages come pretty near to-day to meeting the competition of Europe? The Lakes have worked their problem out despite the fact that their vessels are laid up for months each year while some of their salaries go on and interest charges continue. The ship designed for cotton or tea or sugar or coffee might find an all-year-round use in some port or another.

I have some familiarity with steam engineering, and am a builder of engines largely used as auxiliaries on ships. This makes me aware of the importance of study to the engineering problems involved in the motive power of a vessel. There is much that can be done and doubtless will in the near future be done to reduce the proportion of labor cost in running a ship, through the use of oil fuel on steam boilers or of internal-combustion engines of one kind or another. This path seems now clearly marked out, and yet, though with some diffidence, I venture the suggestion that this leaves out of account two elements of larger importance. We have concentrated our attention and thought upon the cost of running the ship between ports, and I fear too little upon the cost of detaining her in ports.

The making of handling machinery, conveyors, and the like is a well-developed industry in which America takes a leading place. Why not aim, with its aid, to cutting down the stops between operations, or, in other words, the time it takes to unload and load a ship? If this requires the adaptation of special forms of conveying machinery, there are those among us ready to do the work. I believe there are those to whom it would be no impossible problem to make carriers of one form or another that would take package freight directly from cars and deliver it at different places within a ship's hull according to its size, shape, weight, or other factors. Possibly we shall have to devise a form of freight car which is not restricted for its discharge to two small central doors. Possibly we shall have to modify the ship in the details which prevent a flush lever run from dock to deck. Possibly the whole design of the ship's hull must be modified in respect to its

capacity for receiving and discharging freight. In brief, the problem seems to me to be more important to get the goods out of a vessel and other goods into her and to get her earning again than the problem as to what it costs to move her at sea, though I do not minimize the necessary importance of this last. I believe that he who studies the cost of handling freight by carts, of piling it upon the dock by hand, and removing it again to the place where it can be grasped by slings, and rehandling it again in the ship's hull and storing it away will find that if this can, as I believe it can, be largely reduced by specialized apparatus, a blow will have been struck at the cost of shipping freight that may make the further saving in the use of fuel at sea beyond our best practice look like a comparatively small thing. If to this can be added vessels especially designed to carry freight of special kinds, so that something, at least, of the principles applied upon the land may be put in use elsewhere, a new light might dawn upon us in the cost of doing work, especially if these ships were given a large capacity relatively to the average freighter now operating.

I think there is no mechanical difficulty that prevents goods being taken from a car by a conveyor which shall proceed into the ship, either horizontally through a side hatch or vertically through a deck hatch, and shall within that ship descend from deck to dock and then horizontally within her hull deliver the freight to the point where it is wanted. This would not pay for a small vessel, just as we could not carry ore upon the Lakes in loads of 500 or 1,000 tons, but for ships of 10,000 tons cargo it might be profitable. Nor do I expect this to be done quickly, for we ought to have in mind that time is just as necessary an element in development as is money or brains, but that something along this line of thought will be developed and will be a great factor in the cost of transportation at sea, I do believe. And if we, instead of following the same lines of study that our European competitors do, diverge therefrom into original thought on the serious matter of handling cost, possibly we might find a field as new as was that in the Great Lakes.

It would be interesting if some seaport city, wishing to conserve its commerce, would arrange special docks equipped for handling in the most modern way the particular classes of merchandise which were there shipped most largely, and would co-operate with open-minded ship designers in adjusting its apparatus to a ship also equipped for the handling in large

quantities of this same material. If then these terminal facilities so adapted to the goods and the ships could be leased for a term of years to a company that would build and operate the ships, would there not be created a normal preference to which none could object? Would not the vessels proposed, being designed as intelligently in all other respects as they would be specially prepared for receiving and discharging cargo, be able to make many more trips and add largely to their percentage of operating time? Suppose then that they could not carry freight at as low a cost and that there was a lesser margin of profit in a competing rate, they could afford to run at a larger cost by reason of the lesser expense of handling their goods at their terminal. If the company were able to add like facilities at the foreign port or to the extent that it was able to better the facilities there that its rivals had, it would add a still further element of competing power.

I appreciate that the profession of designing vessels, both in their hulls and in motive power, is in a state of flux, and it is my hope that out of this very condition that may come which is of great value to the American marine. I am entirely willing to provide for discriminating duties in favor of American bottoms if so be, however, that it shall be insured that there is to be no increase in transportation rates on that account. I see no harm in a preferential capitation tax on immigrants in American ships or some preference import charges or in tonnage tax, provided these or any of them can be done without interference with treaties or without injuring that enormous export trade upon which we are coming increasingly to depend. But none of these preferences have a moral right to exist until American designers in all the branches that make up the marine shall have cast aside the weight of tradition and shall have put into their professional work that same executive imagination which has given us the telephone, which produced the wireless telegraph, and which is now giving us the aeroplane.

It must be assumed as a fact that the American people will not permit subsidies beyond paying for a reasonable amount of work actually done in carrying the mails, nor will they allow the wages for American sailors and officers to be cut down. These are fixed facts against which it is useless to protest. Nor is there in my judgment any panacea available or any scheme for getting prosperous quickly. The work must go on step by step. An excessive conservatism must be abandoned. It will hardly do to continue

the process by which within a month an apparatus has been required for a ship which took 700 cubic feet, weighing 3,800 pounds, while the same manufacturer who furnished it was ready to supply an apparatus taking 200 cubic feet and weighing 1,800 pounds, which was more efficient and which had been tried upon hundreds of ships. This sort of thinking must mean and ought to mean loss.

While time is, as has been said, essential to any permanent development, it is also true that in this profession as in others it is a good rule to do unto the other fellow as he wants to do unto you and to do it first.

May I sum up briefly. The cost of construction in this country has been and is being reduced. From certain circumstances it is little greater to-day then it is abroad. The labor and victual cost of operating cannot be reduced in rate, but it may be reduced in proportion, both in the power of the ship and of her cargo. Neither of these, it seems to me, can very much longer stand in our way if we are prepared to match terminal facilities to the goods we are to carry and ships to both. And, finally, unbelief is a costly luxury. My grandfather was hustled out of the New York Produce Exchange because he said there would one day be a railroad to the Mississippi River. I was told more than once that elevated railroads could never succeed in New York. There are still men who talk doubtfully about the moving platform, though it carried hundreds of thousands with perfect success in Paris twelve years ago. There is hardly one of the great transforming ideas with which we are now all familiar that had not to bear the brunt of unbelief and ridicule. The Atlantic cable was a joke for years, and the first subway built in New York was knocked about from banker to banker till one was found with vision sufficient to take it up.

The suggestions you have so patiently permitted me to make may be valueless, but they are not so because they are different from anything now known, nor are they so because in some way something may have been tried in that direction and found unsuccessful. It is the normal course of invention that men succeed where others fail, and I have sufficient confidence in the trained imagination of American engineers to believe as they have accomplished in mechanics and in electricity and in industry that which makes them the equals of any, so they will not be found wanting in the successful application of their thought to our merchant marine.

Deaths, 1912.

Thomas Andrews, Jr.

William W. Bates.

Emil L. Boas.

Robley D. Evans.

Clement A. Griscom.

Geo. W. Melville.

Walter A. Post.

John C. Silva.

Henry W. Spangler.

D. Howard Spear.

Samuel W. Stanton.

Francis H. Stillman.

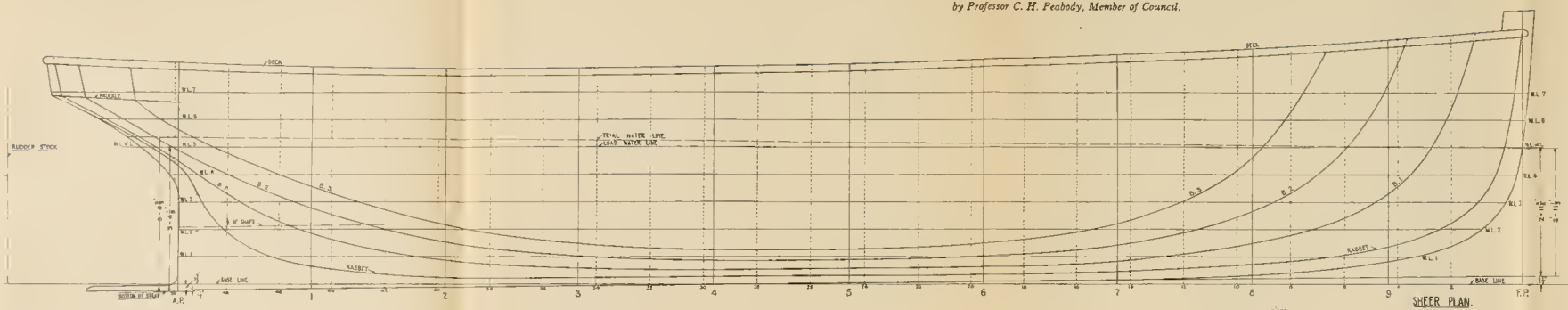
Roger P. Stebbins.

Samuel B. Thomas.

J. W. Lowry Waters.

Howard Wood.

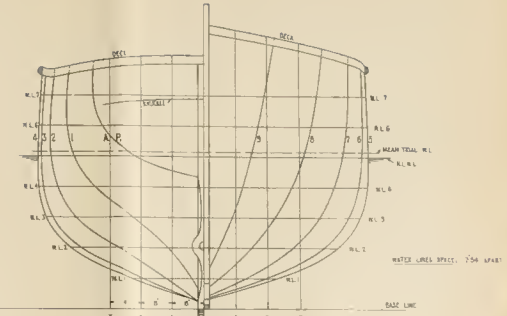
To illustrate paper on "Experiments on the Fulton and the Froude," by Professor C. H. Peabody, Member of Council.



SHEER PLAN.

STATIONS SPACED 3'-089 APART
FRAMES SPACED 14⅓" APART

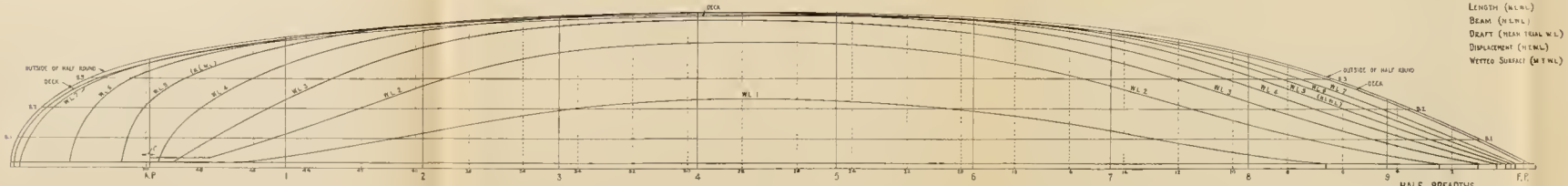
NOTE LINES ARE DRAWN TO OUTSIDE OF PLANKING



BODY PLAN.

PRINCIPAL DIMENSIONS.

LENGTH B.P.	30' - 10⅝"
LENGTH O.A.	34' - 4"
LENGTH (N.L.W.L.)	31' - 9½"
BEAM (N.L.W.L.)	7' - 0⅛"
DRAFT (MEAN TRIAL W.L.)	3' - 3"
DISPLACEMENT (N.L.W.L.)	22160 LBS (S.W.)
WETTED SURFACE (M.T.W.L.)	289 SQ. FT.



HALF BREADTHS.

NAVAL ARCHITECTURE DEPARTMENT

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

FAIRED LINES

OF

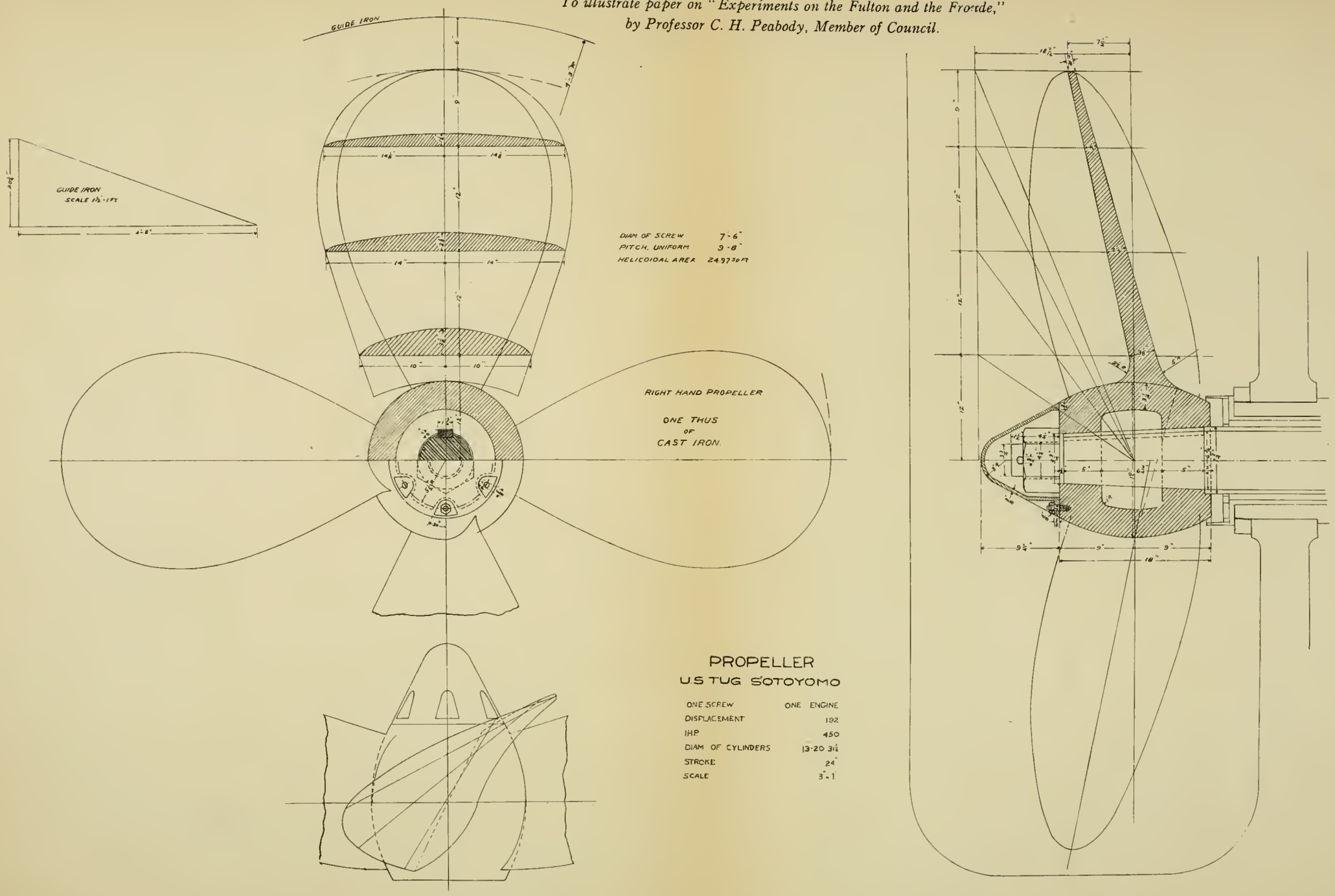
"FULTON"

SCALE 1" = 1' TAKEN FROM WORK

BOSTON, MASS. 5: AG 12

SCALE

To illustrate paper on "Experiments on the Fulton and the Froude," by Professor C. H. Peabody, Member of Council.



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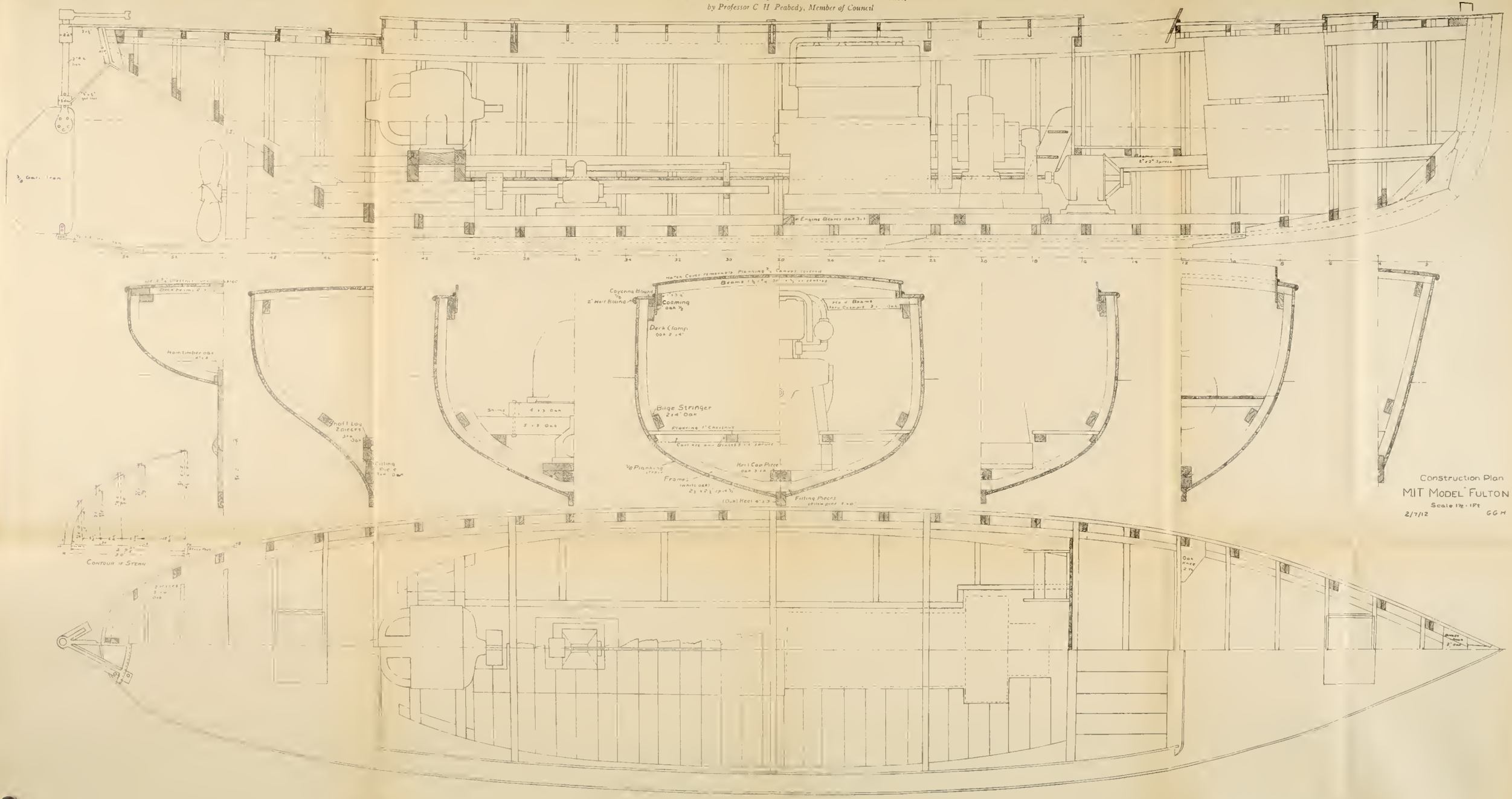

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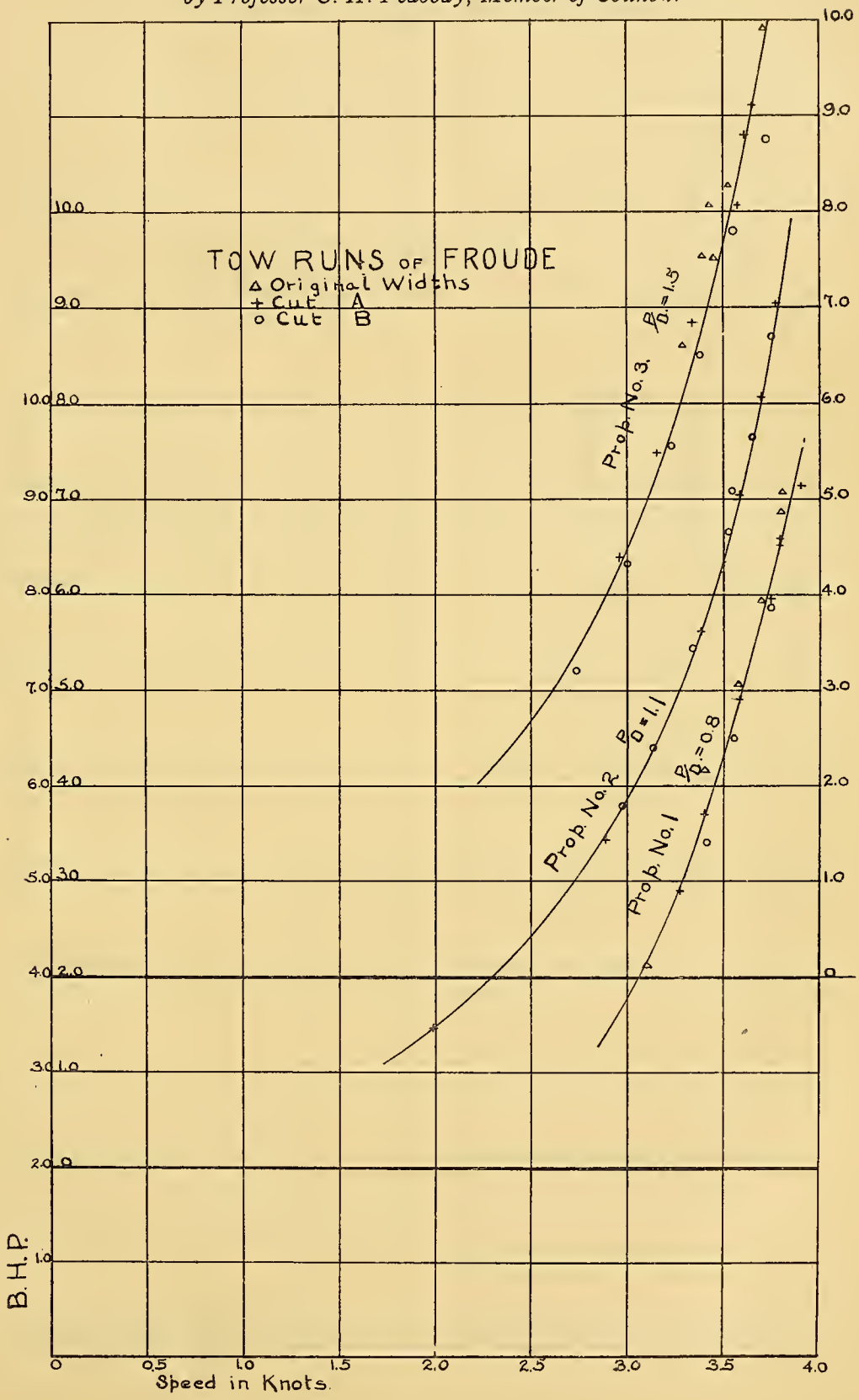

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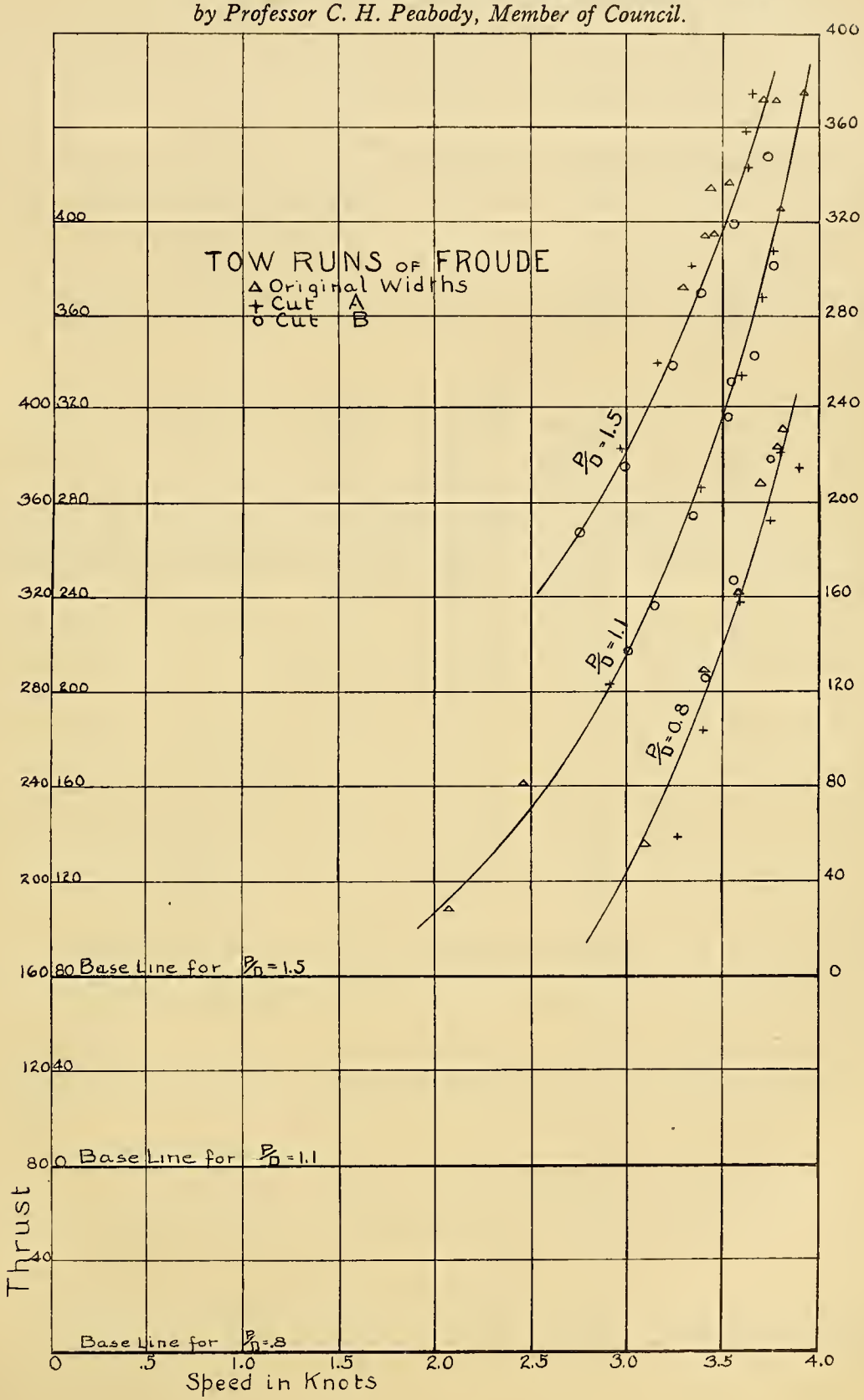

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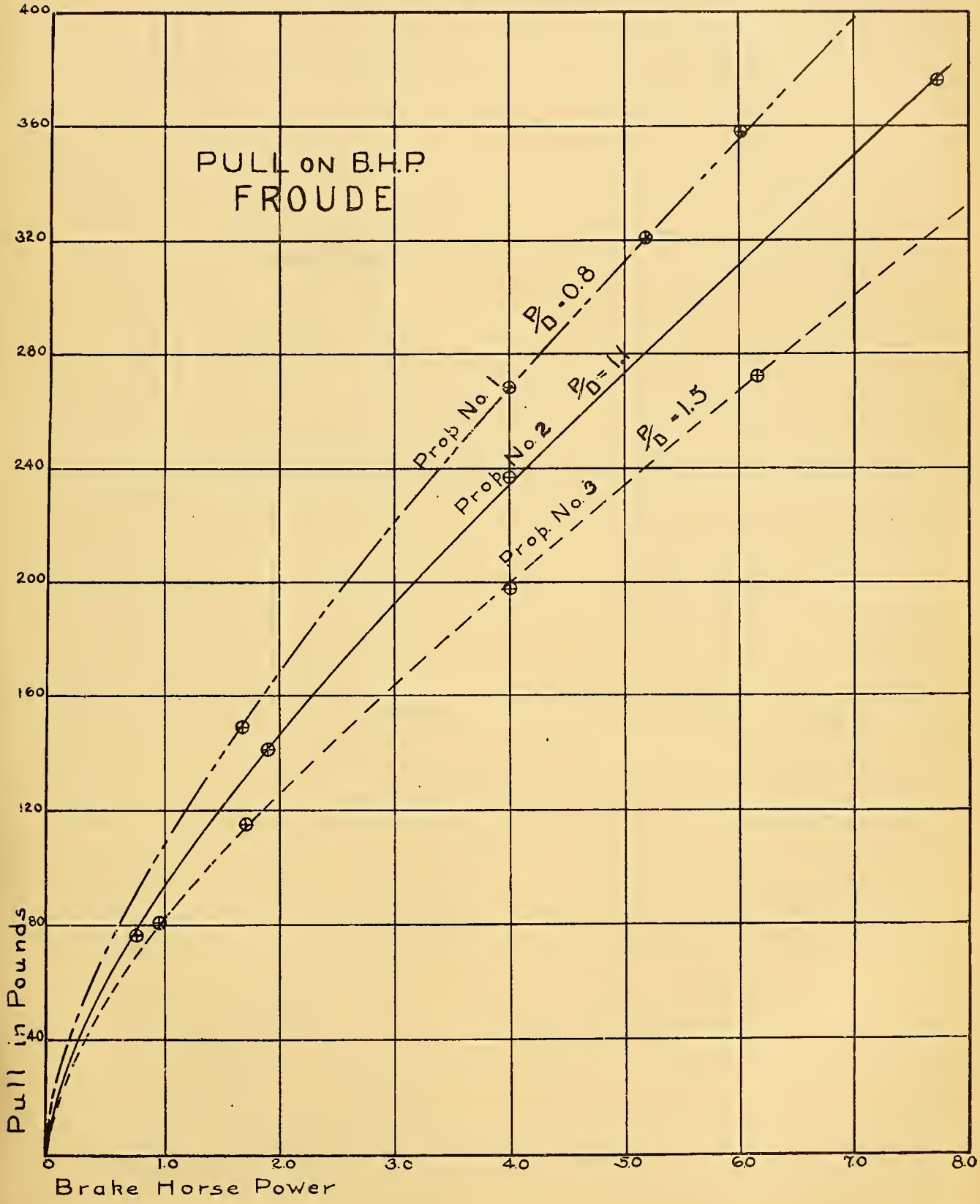

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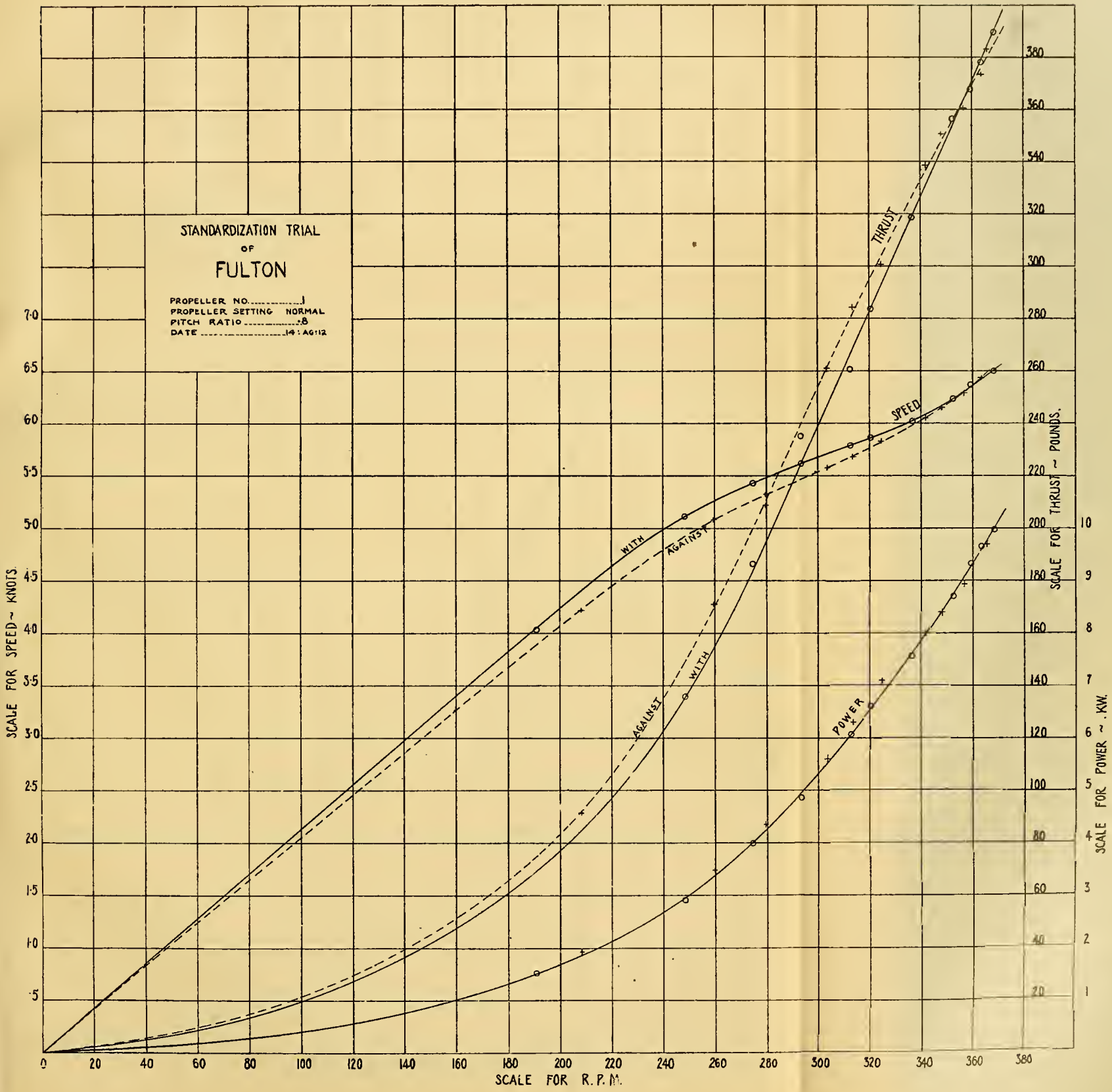

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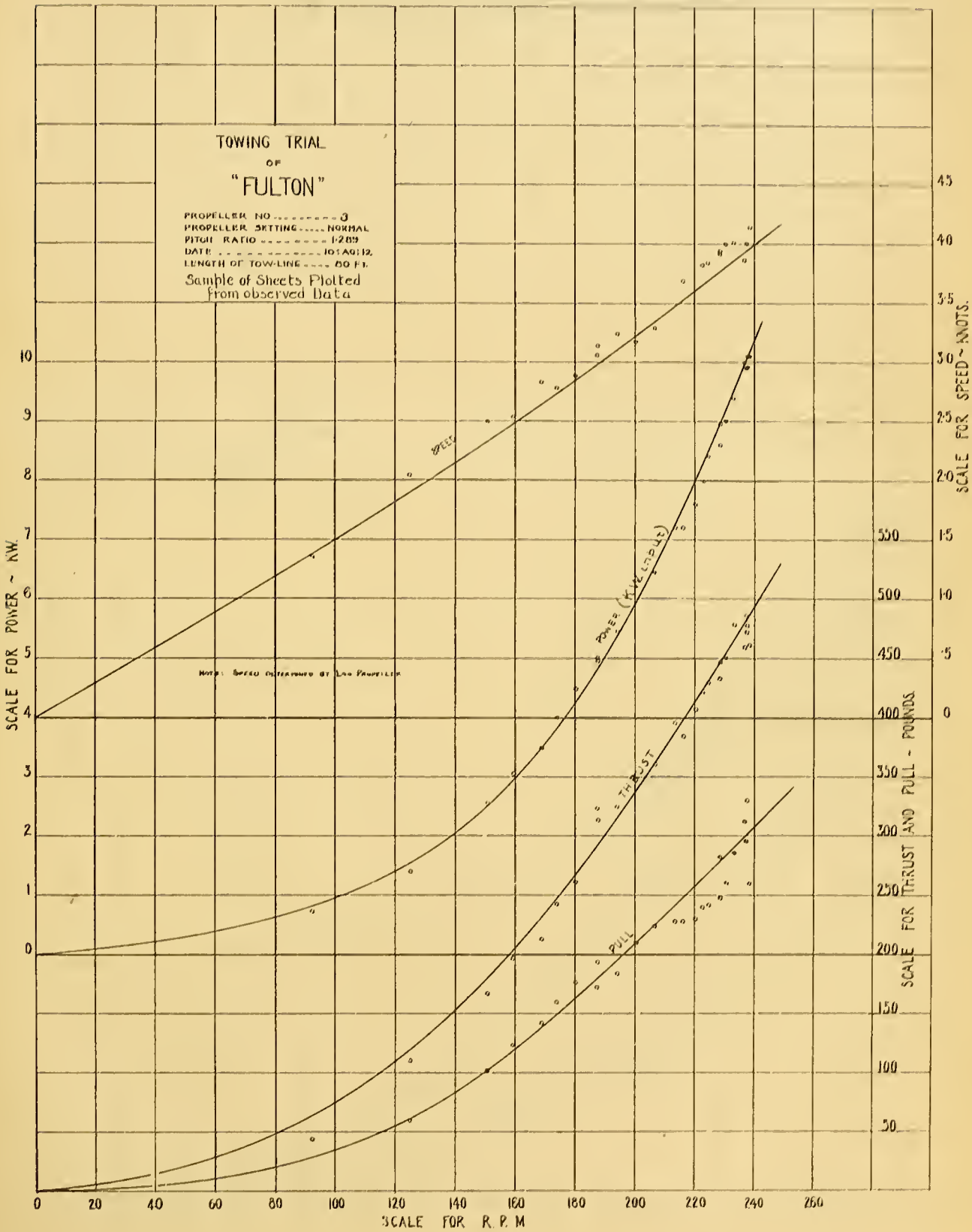

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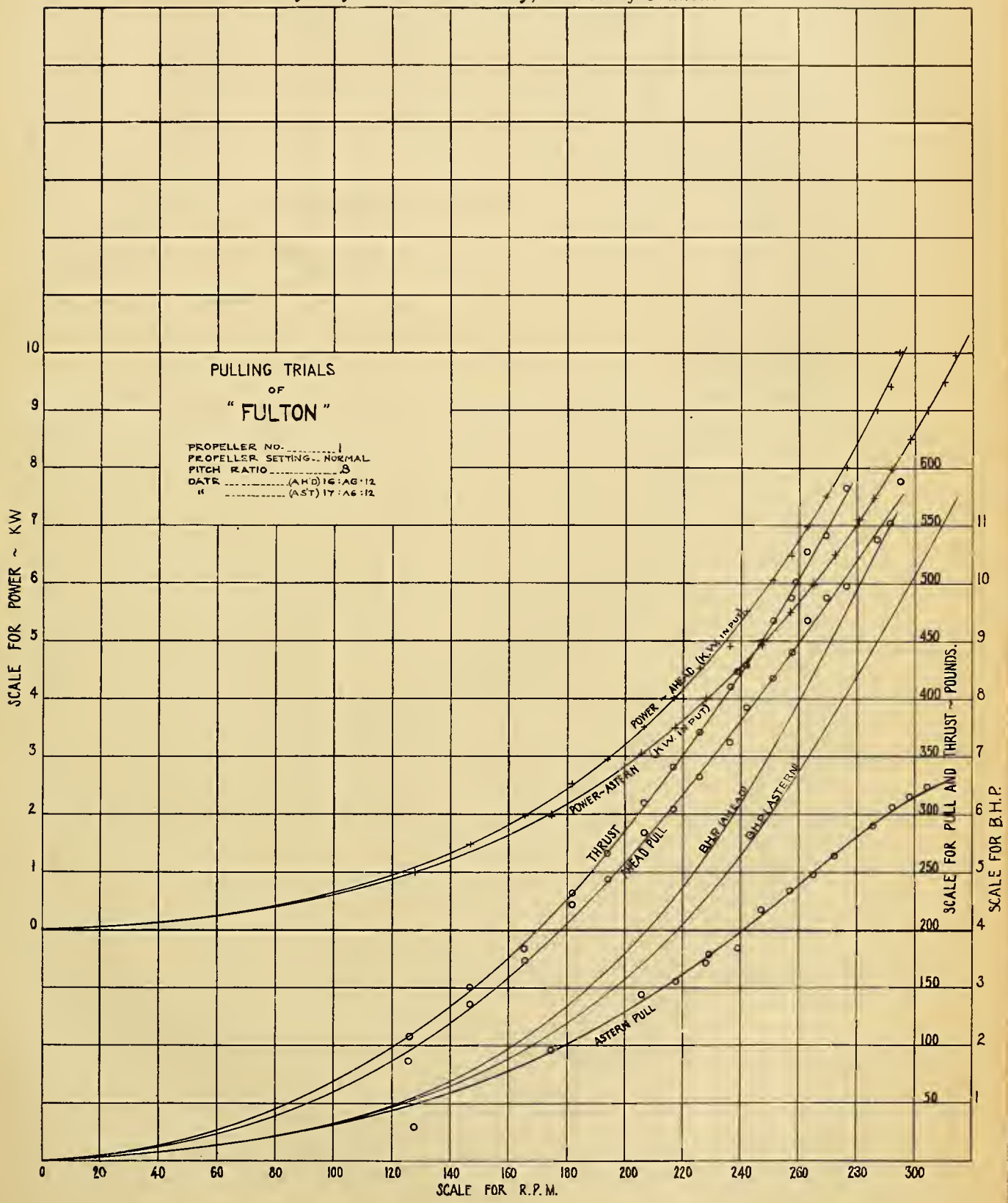

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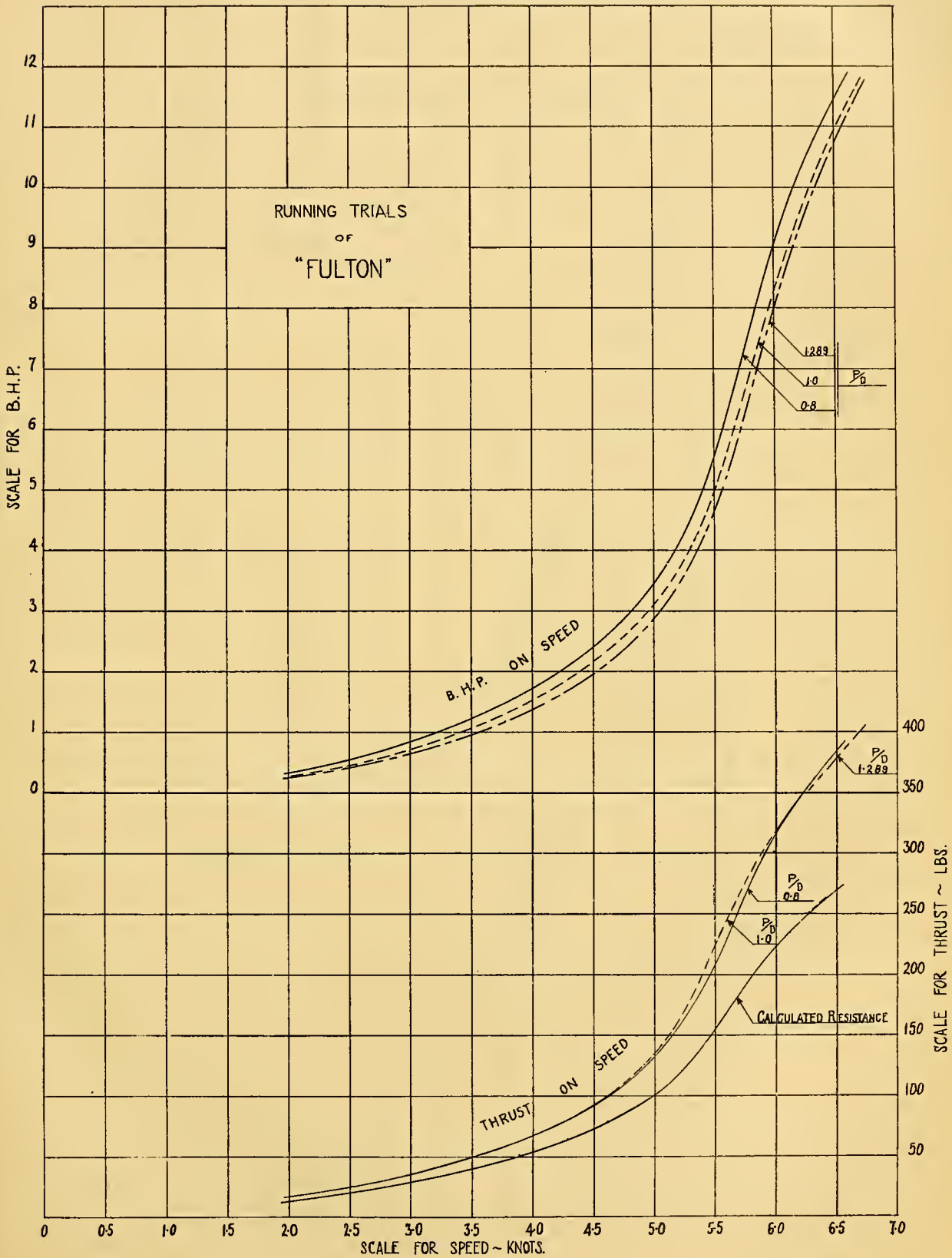

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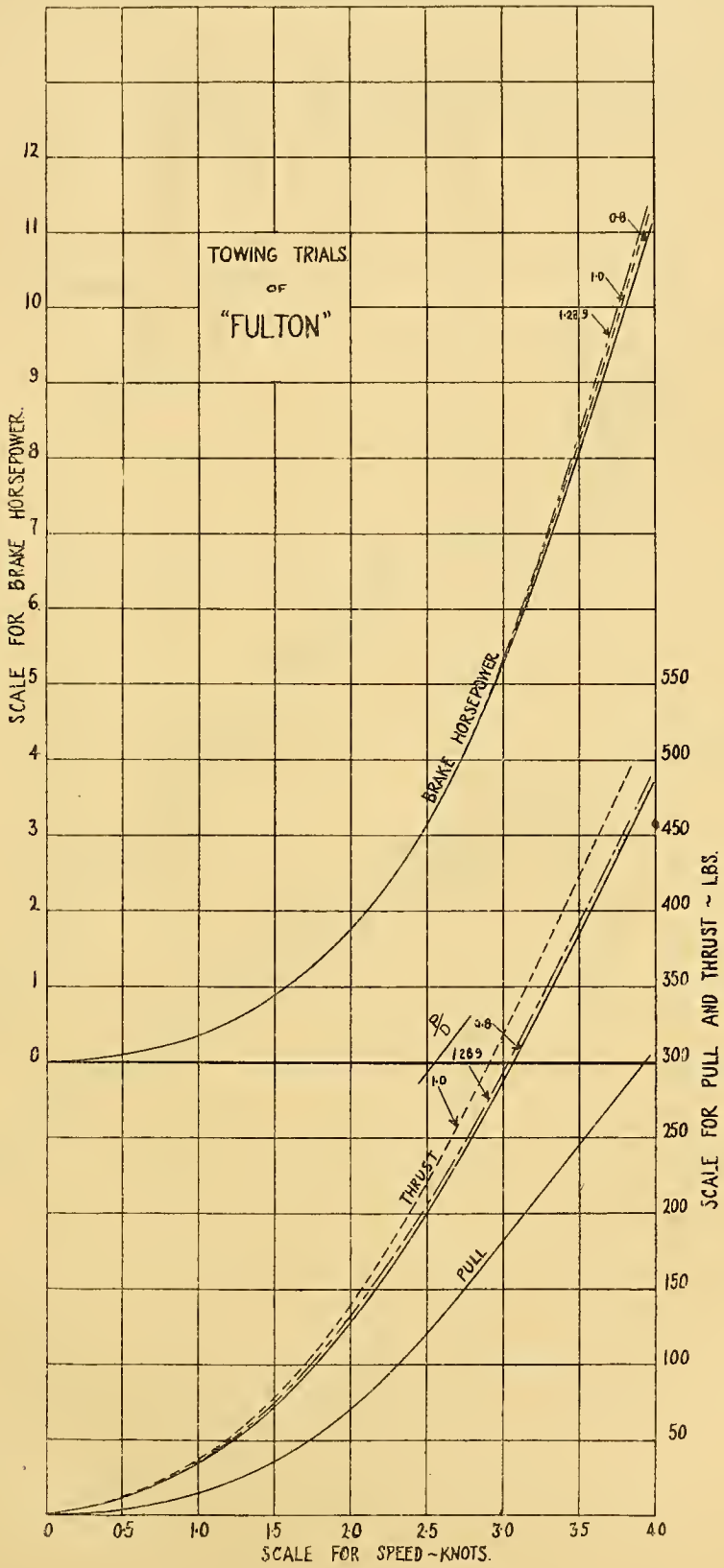

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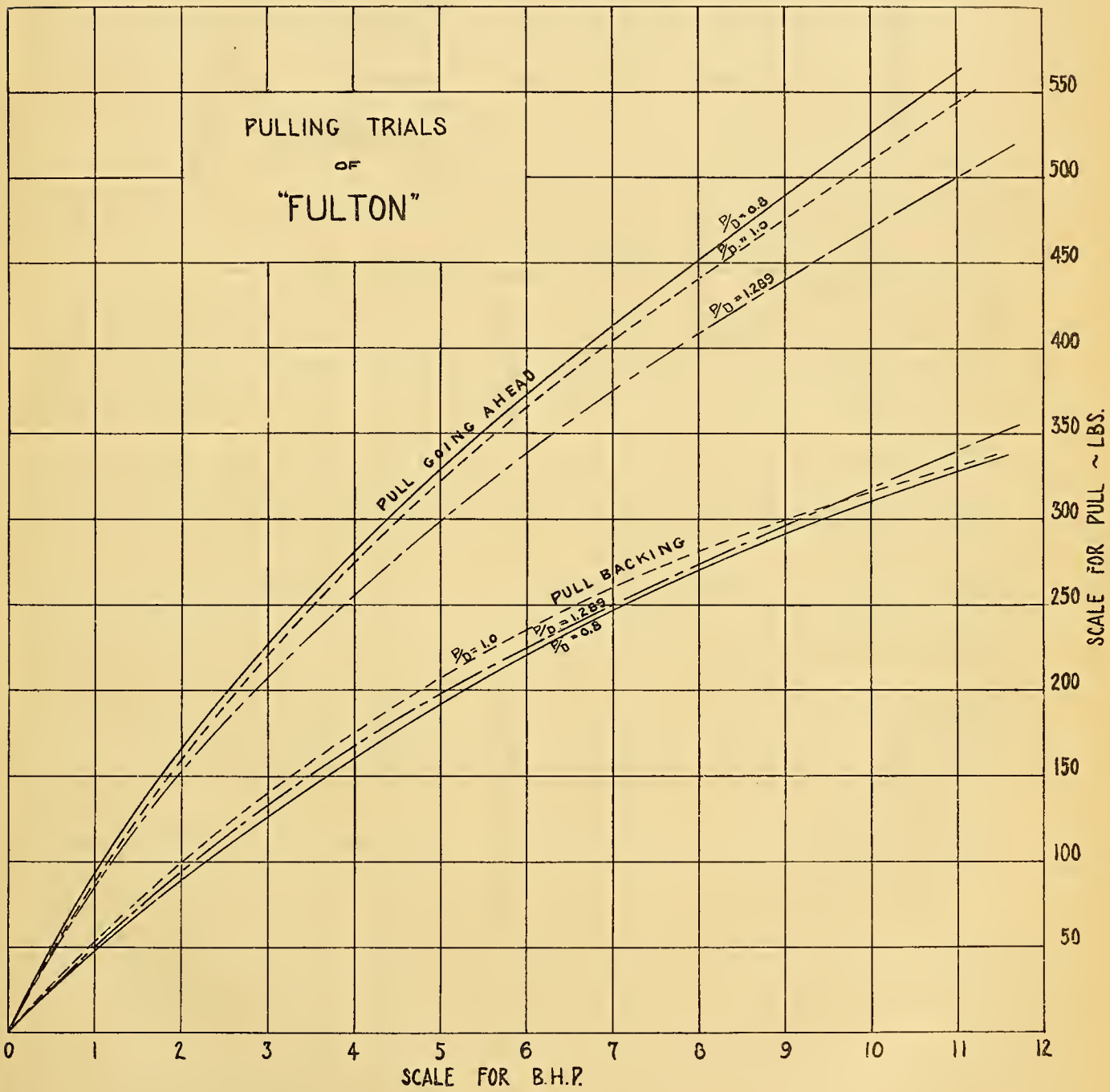

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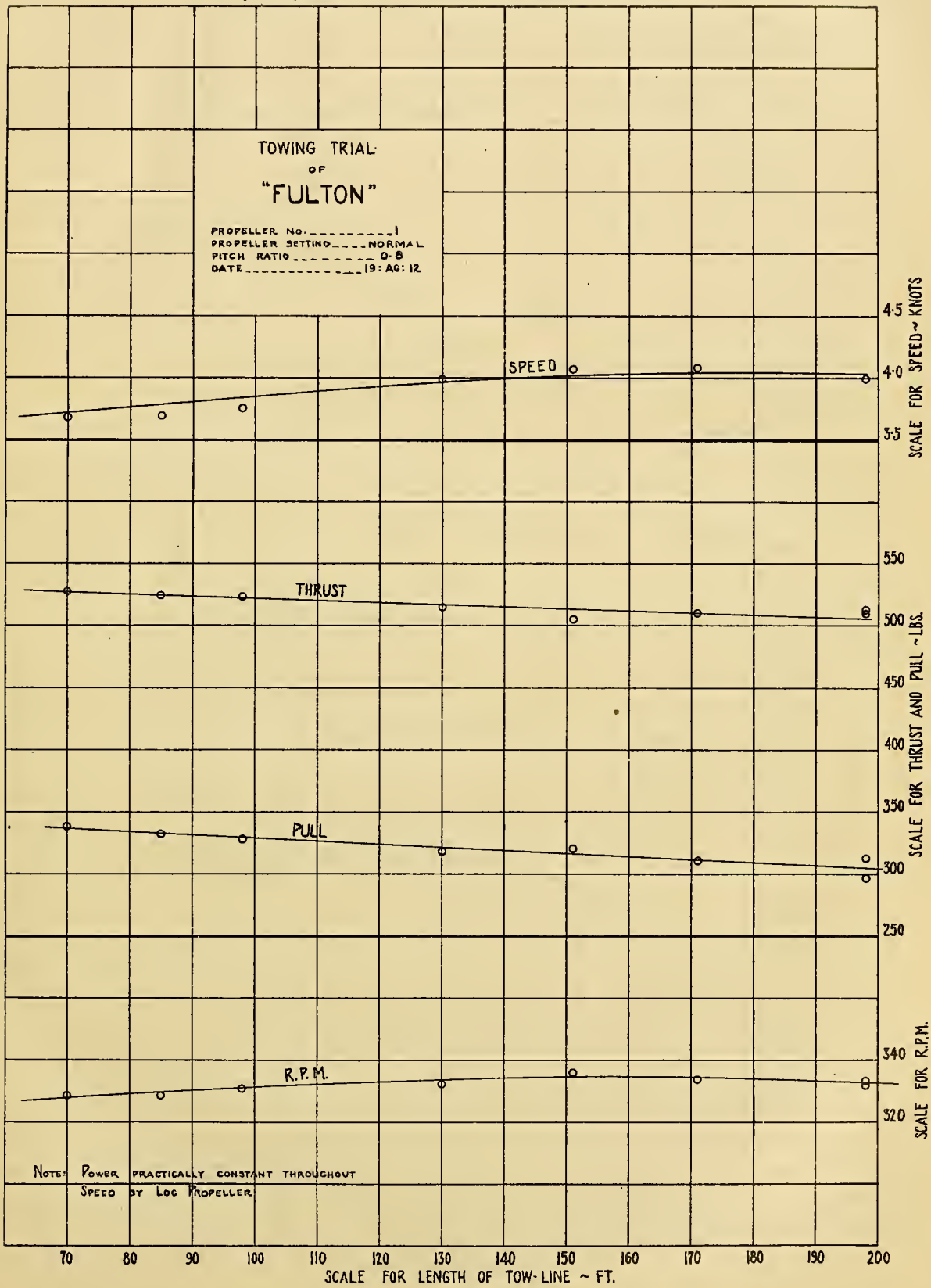

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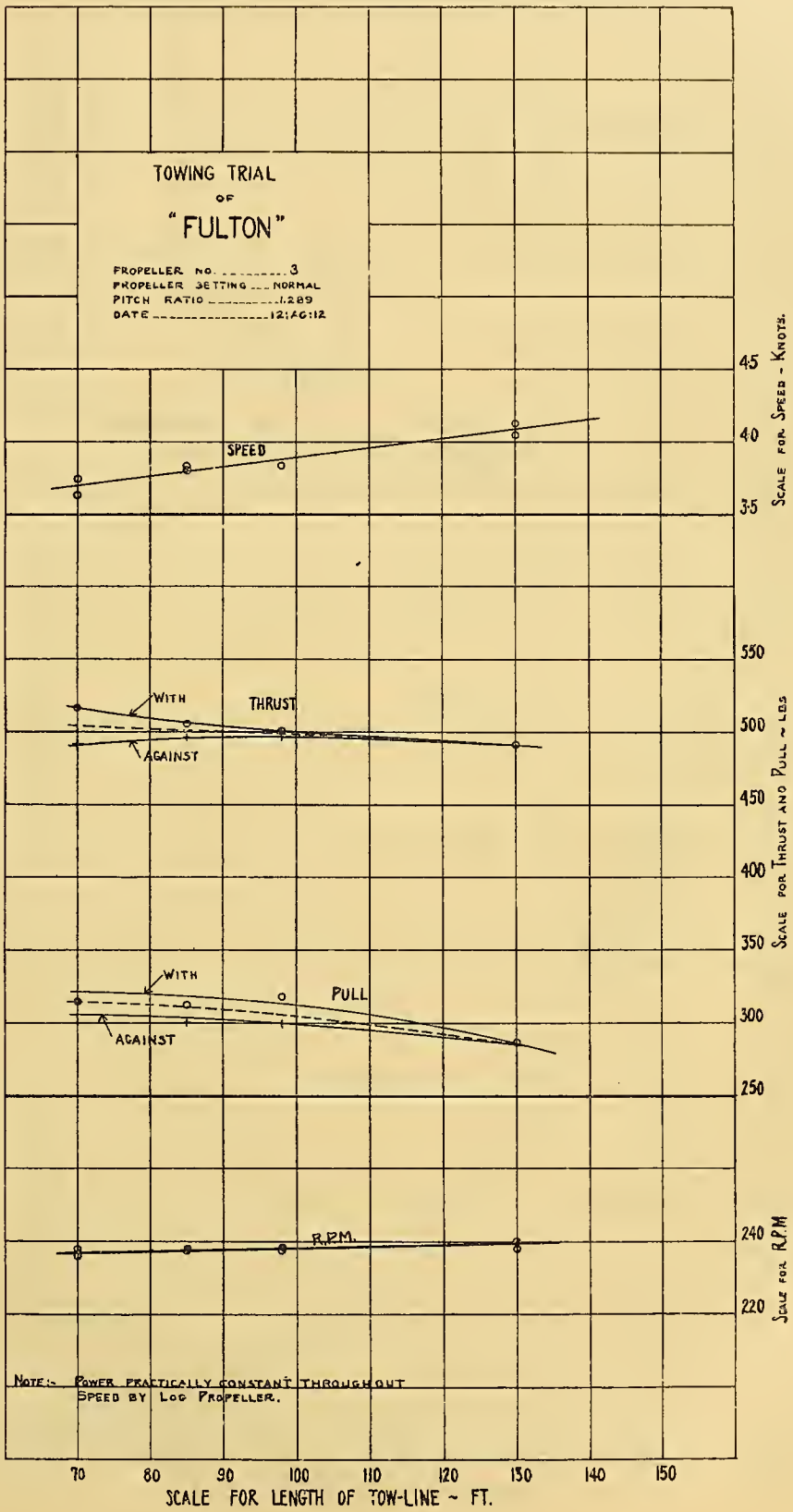

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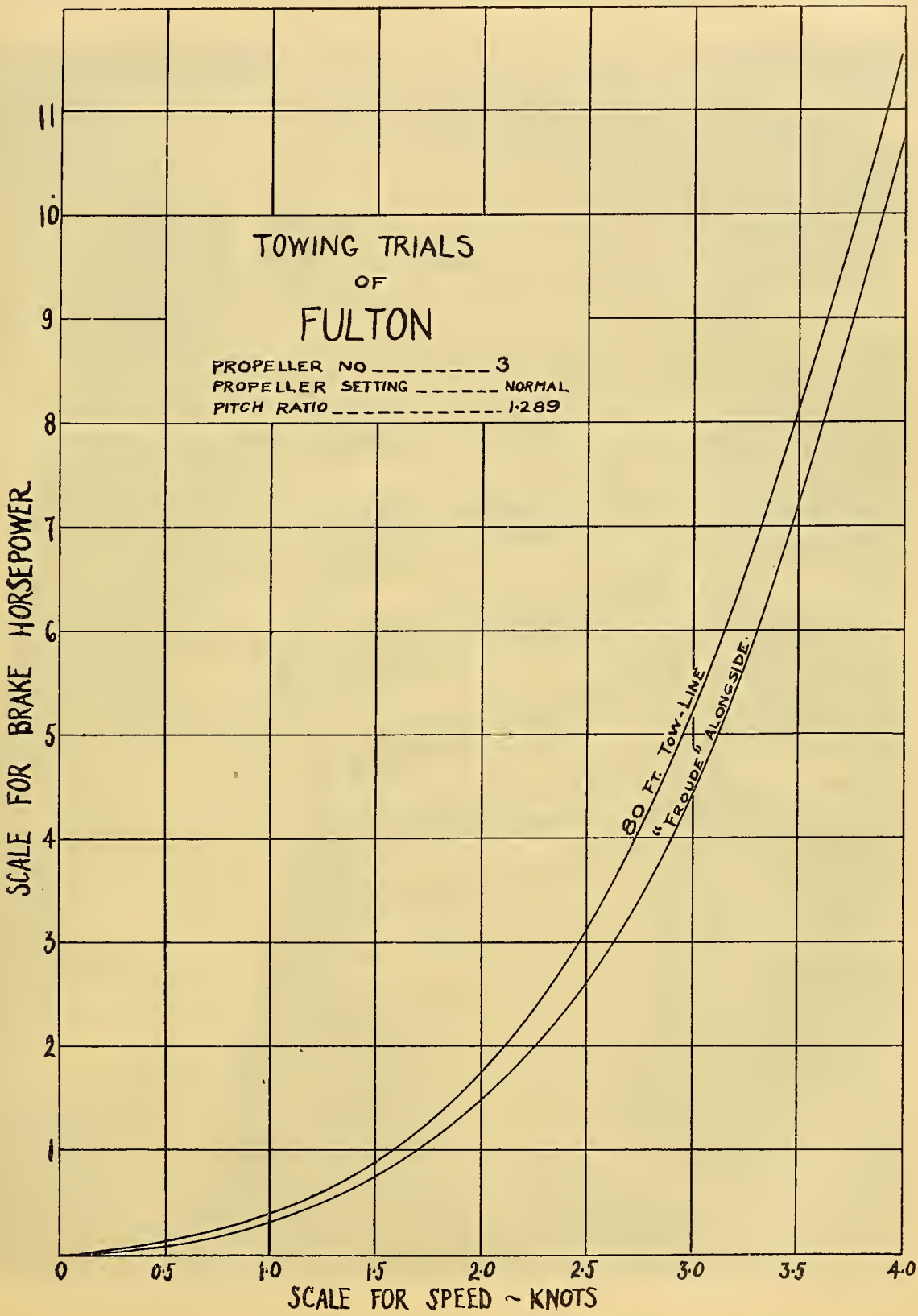

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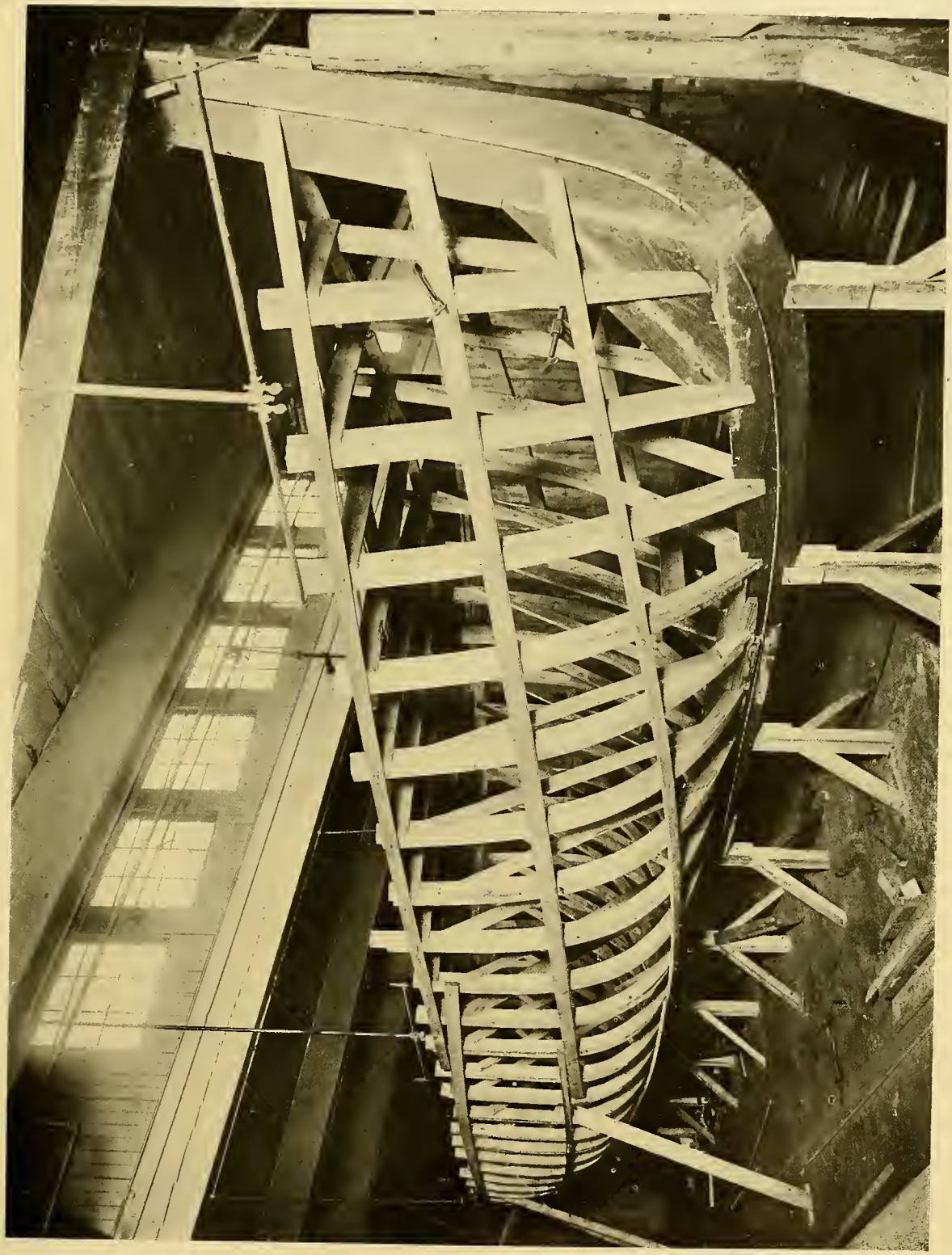
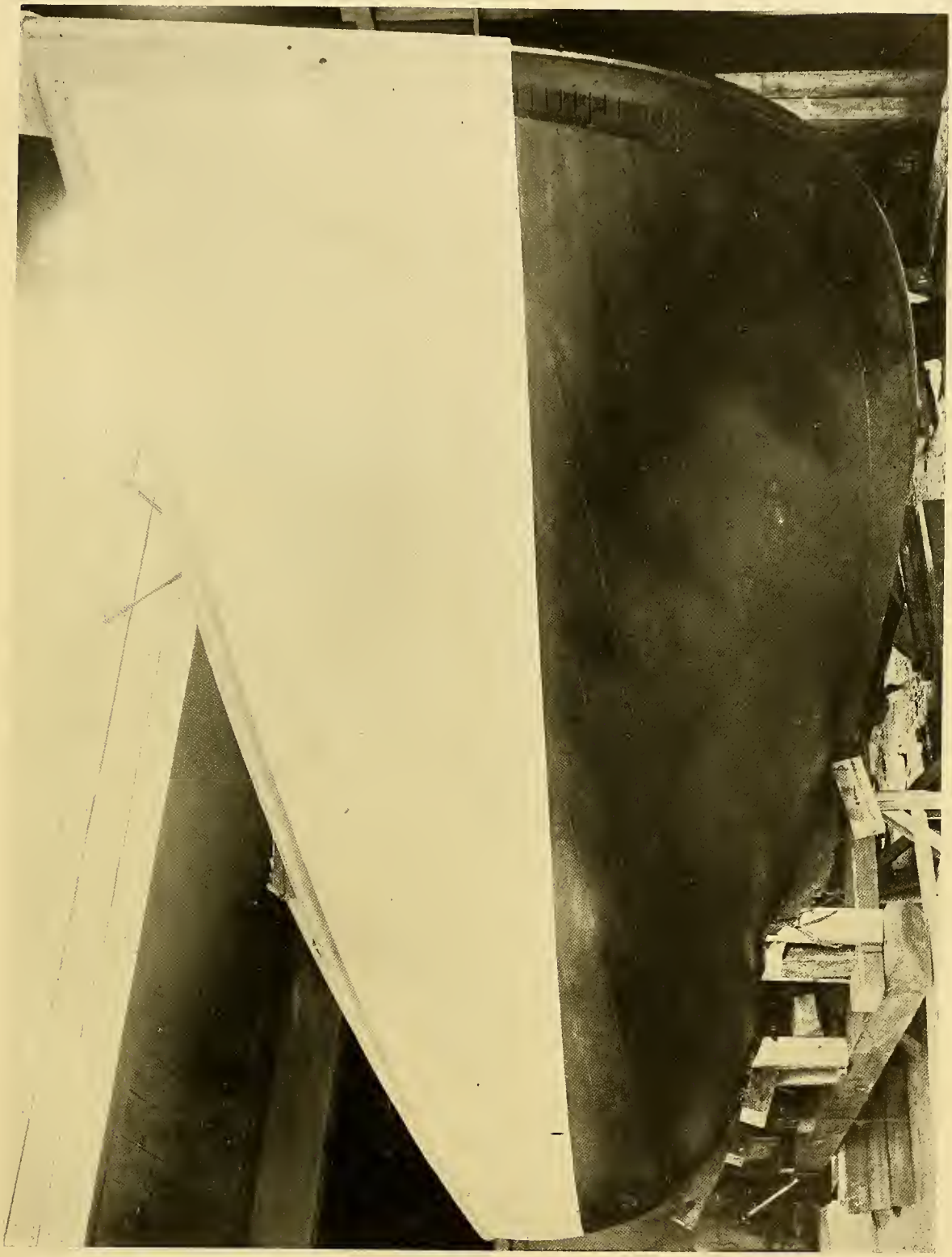


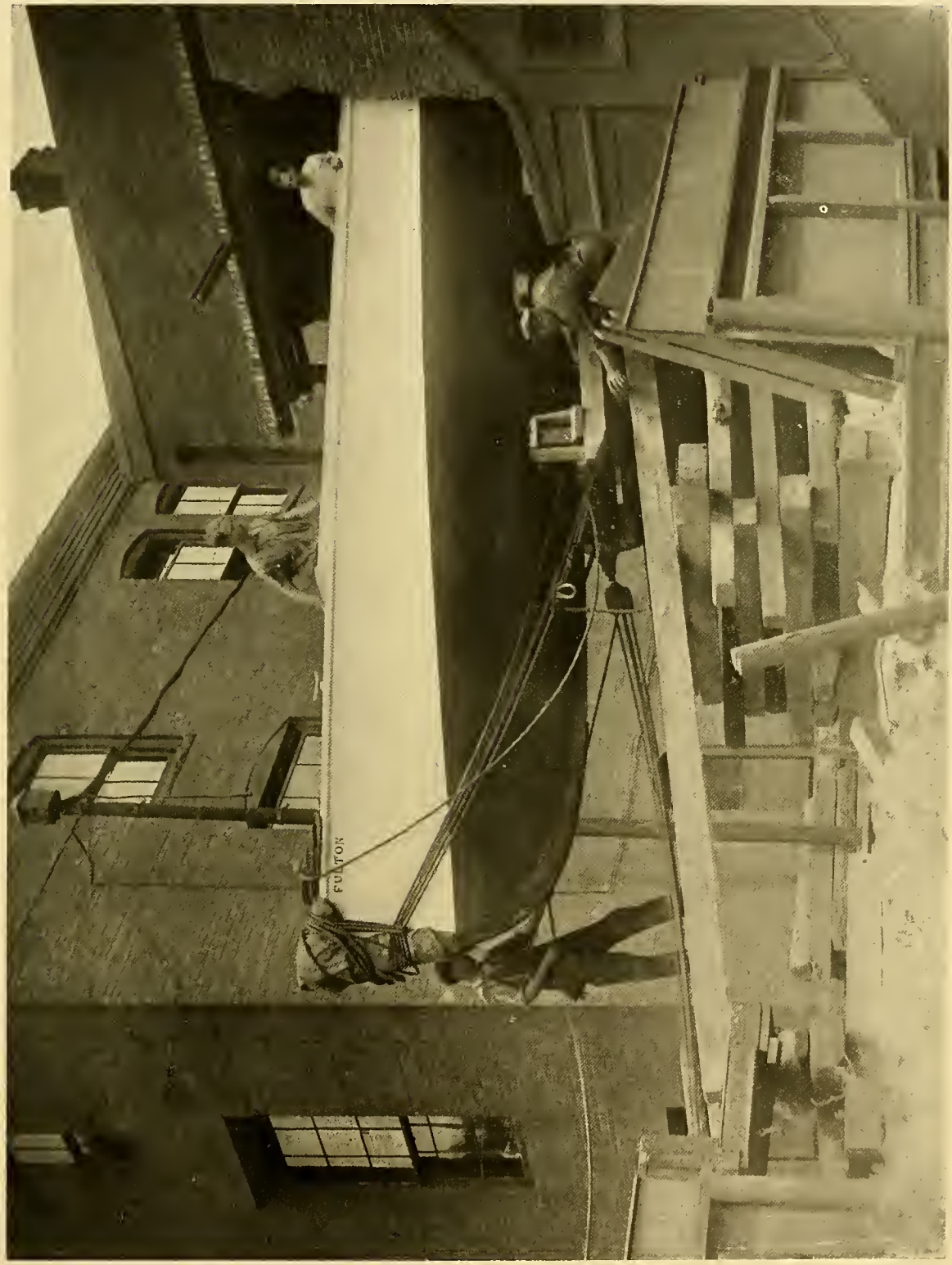
FULTON IN FRAME.

To illustrate paper on "Experiments on the Fulton and the Froude," by Professor C. H. Peabody, Member of Council.



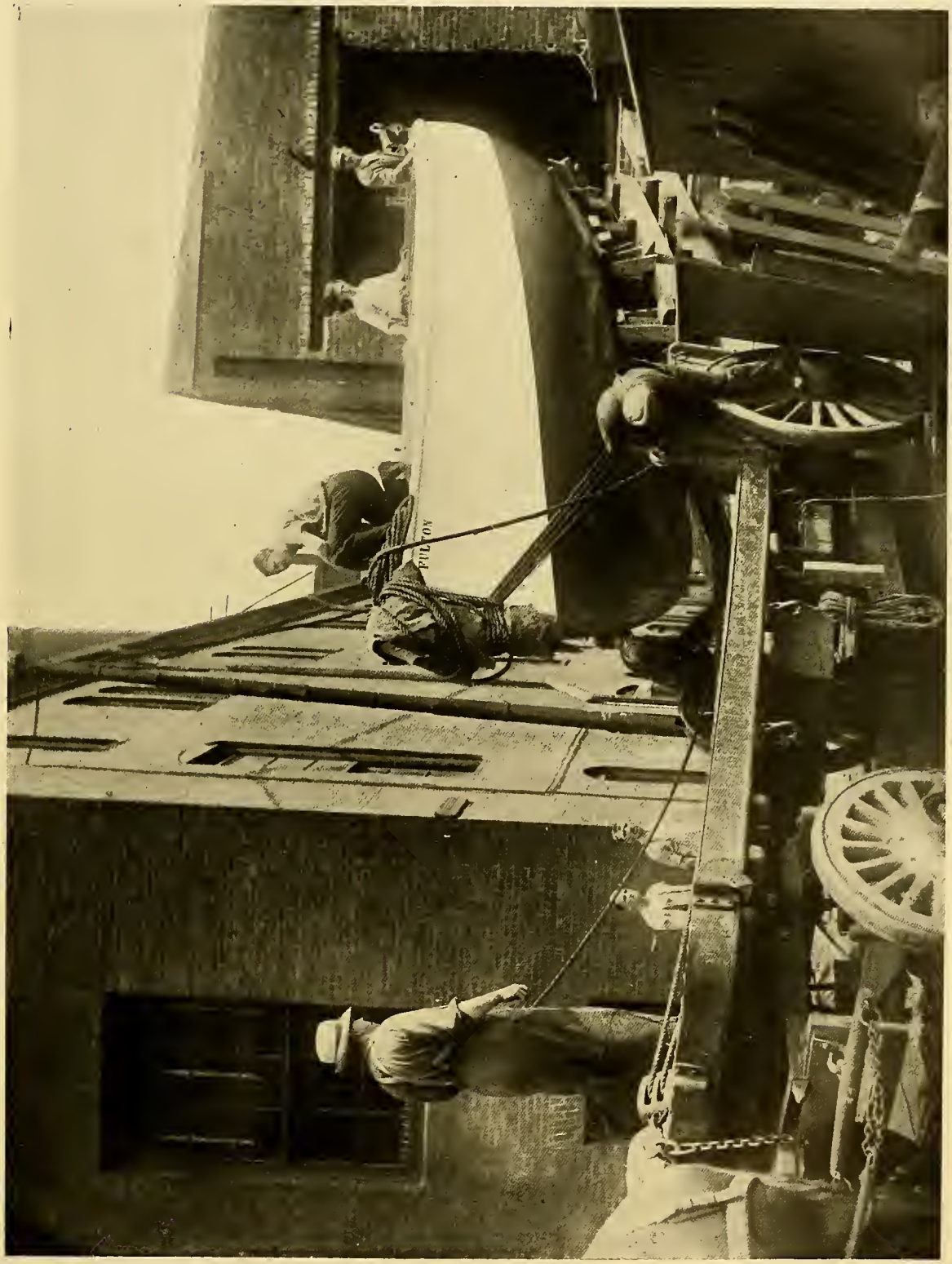
FULTON PLANKED.

To illustrate paper on "Experiments on the Fulton and the Froude," by Professor C. H. Peabody, Member of Council.



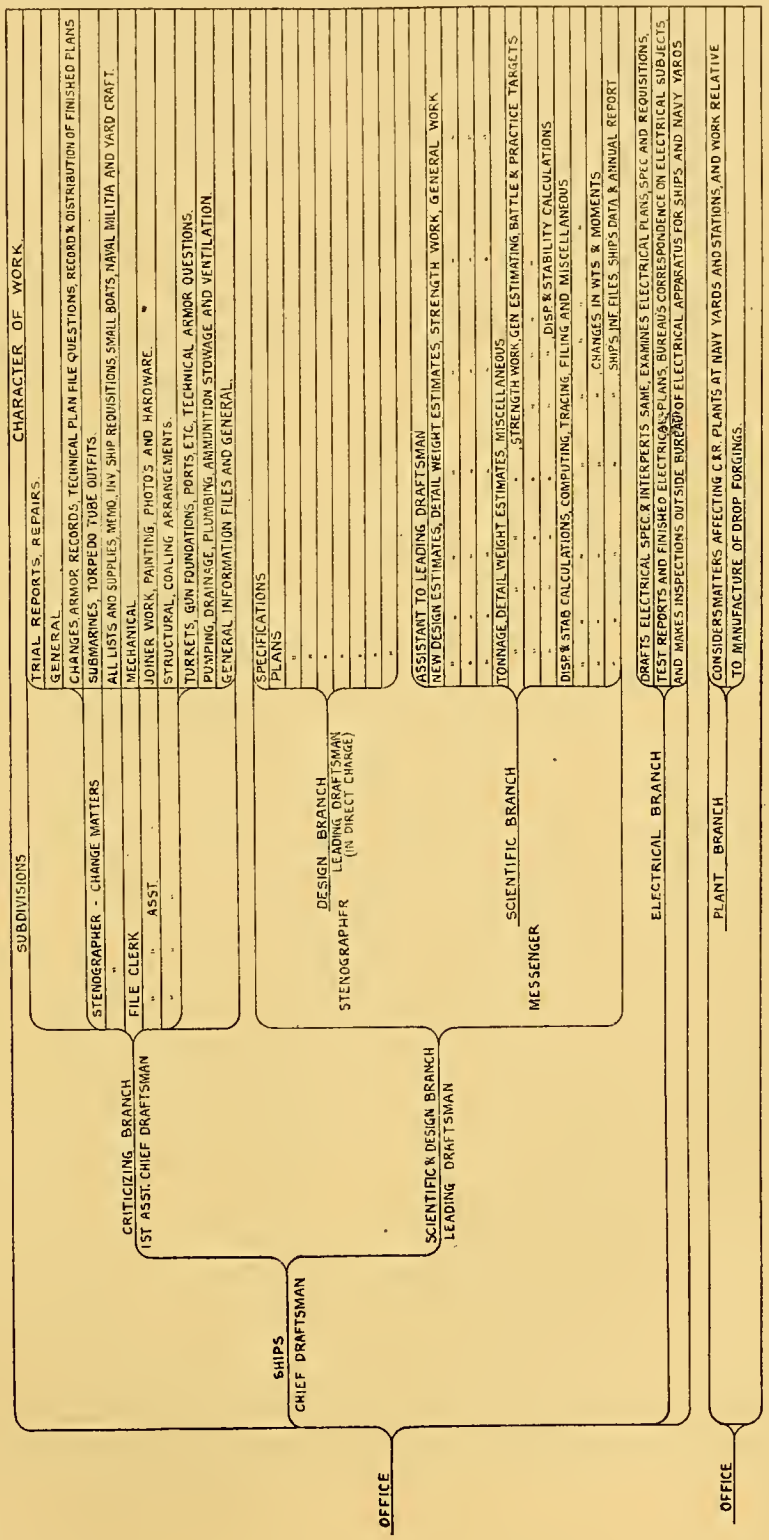
Exit from Building Shed.

To illustrate paper on "Experiments on the Fulton and the Froude," by Professor C. H. Peabody, Member of Council.

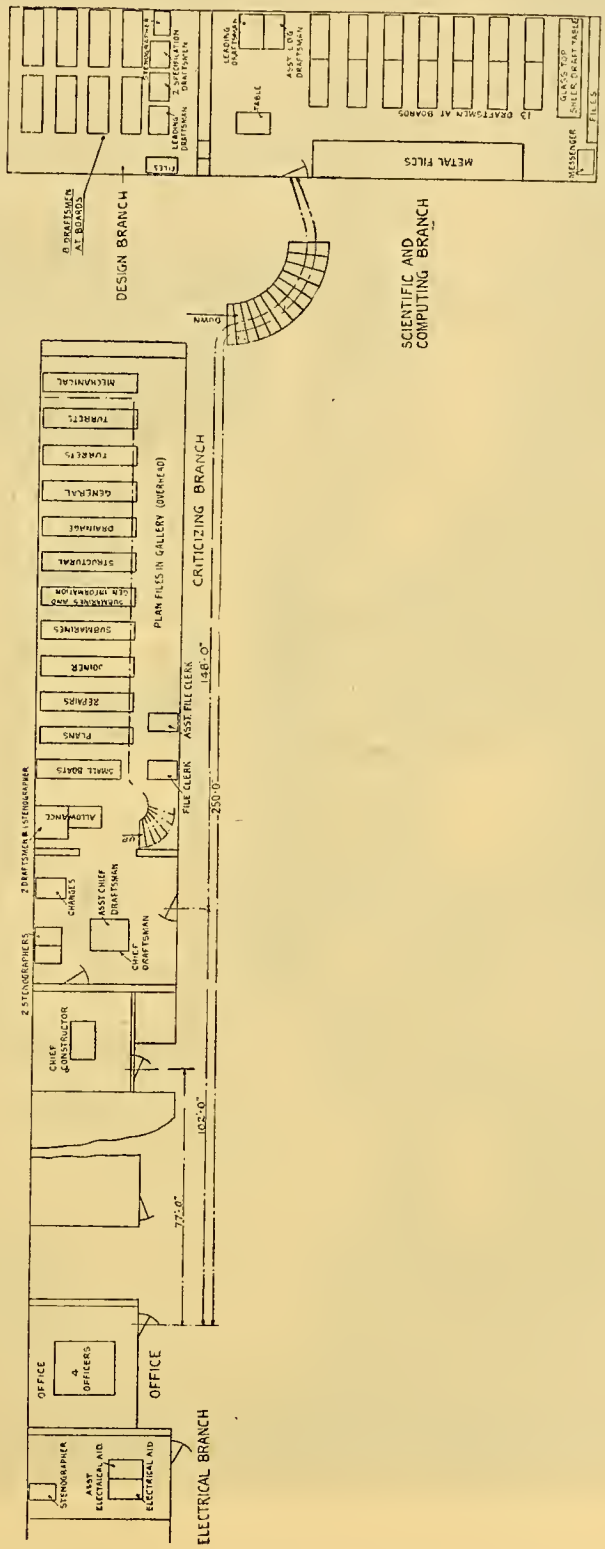


Loading into Truck.

To illustrate paper on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. Navy, Member.



To illustrate paper on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. Navy, Member.



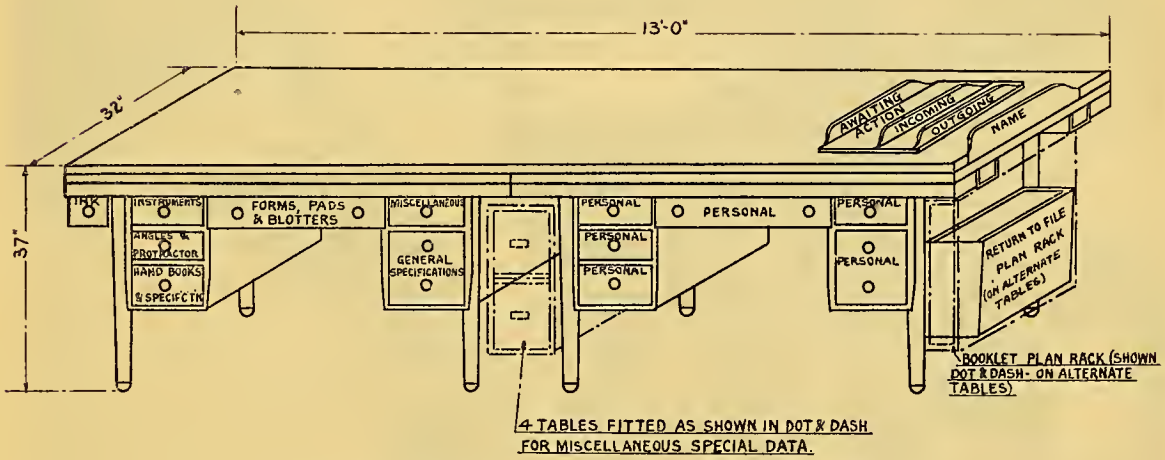
To illustrate paper on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. Navy, Member.

THE OFFICE.

To illustrate paper on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. Navy, Member.

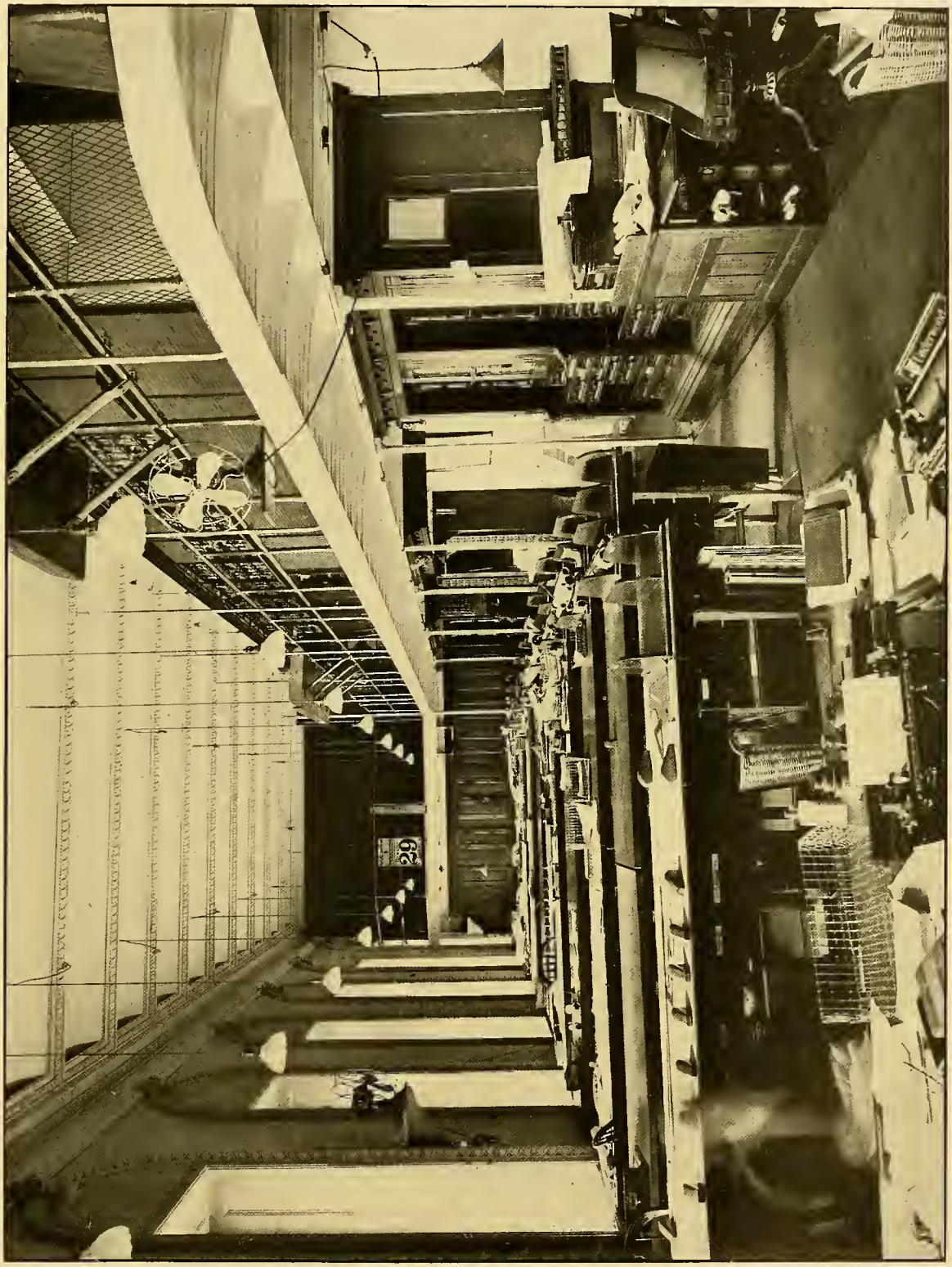
Electric Branch.

To illustrate paper on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. Navy, Member.



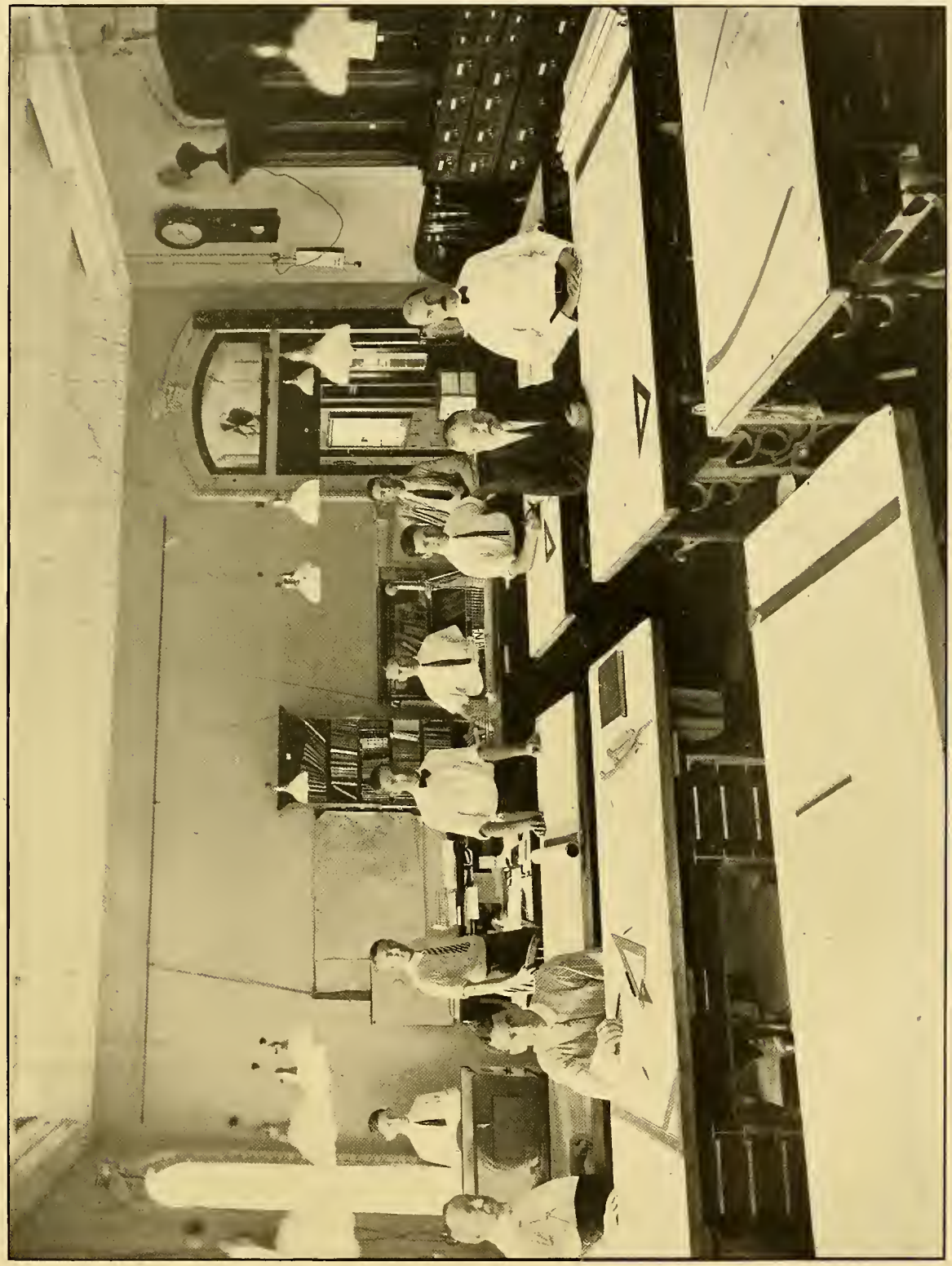
DRAWING TABLE USED IN DRAFTING ROOM, CRITICIZING BRANCH, BUREAU C.& R.

To illustrate paper on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. Navy, Member.



THE CRITICISM BRANCH.

To illustrate paper on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. Navy, Member.

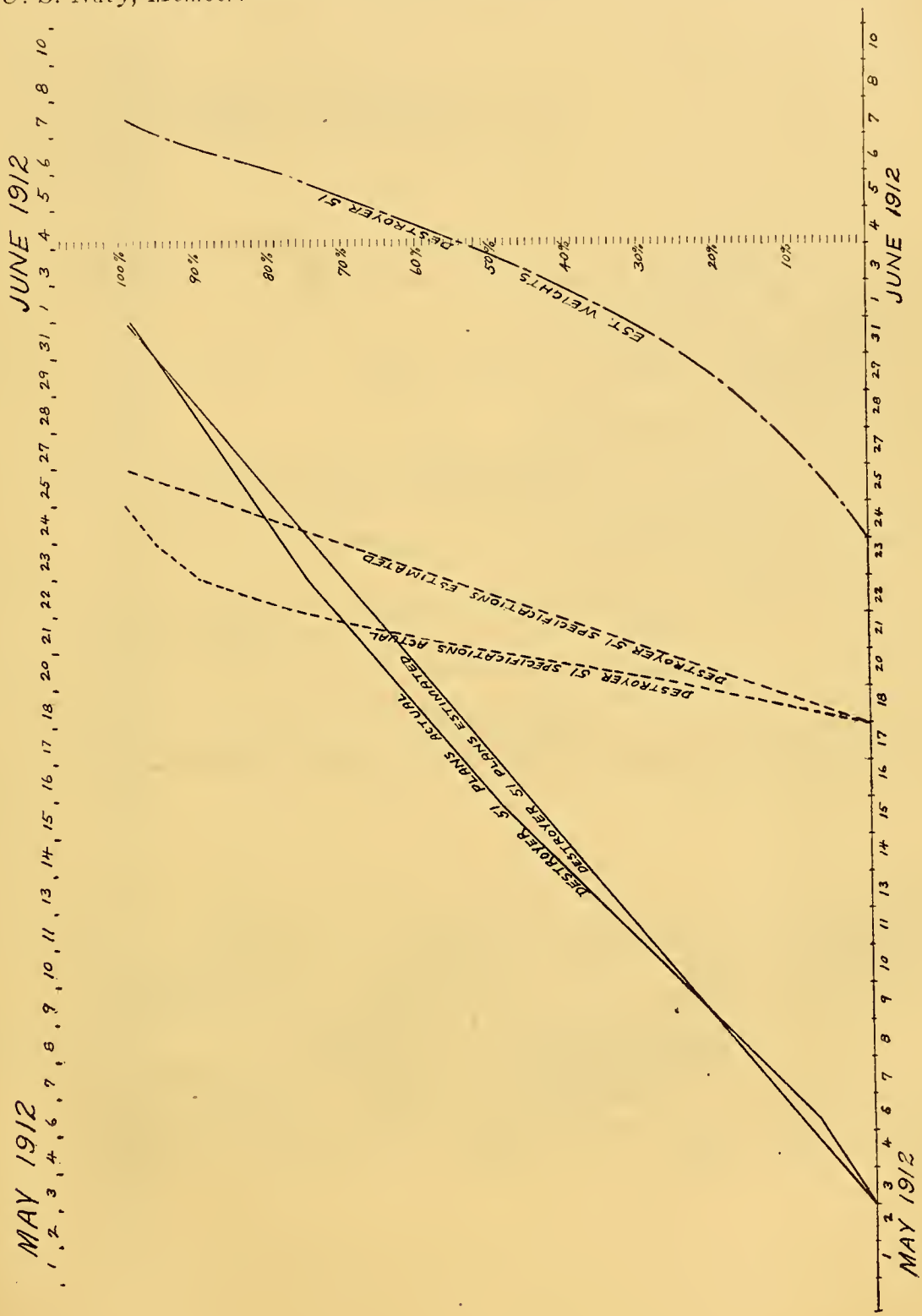


THE DESIGN BRANCH.

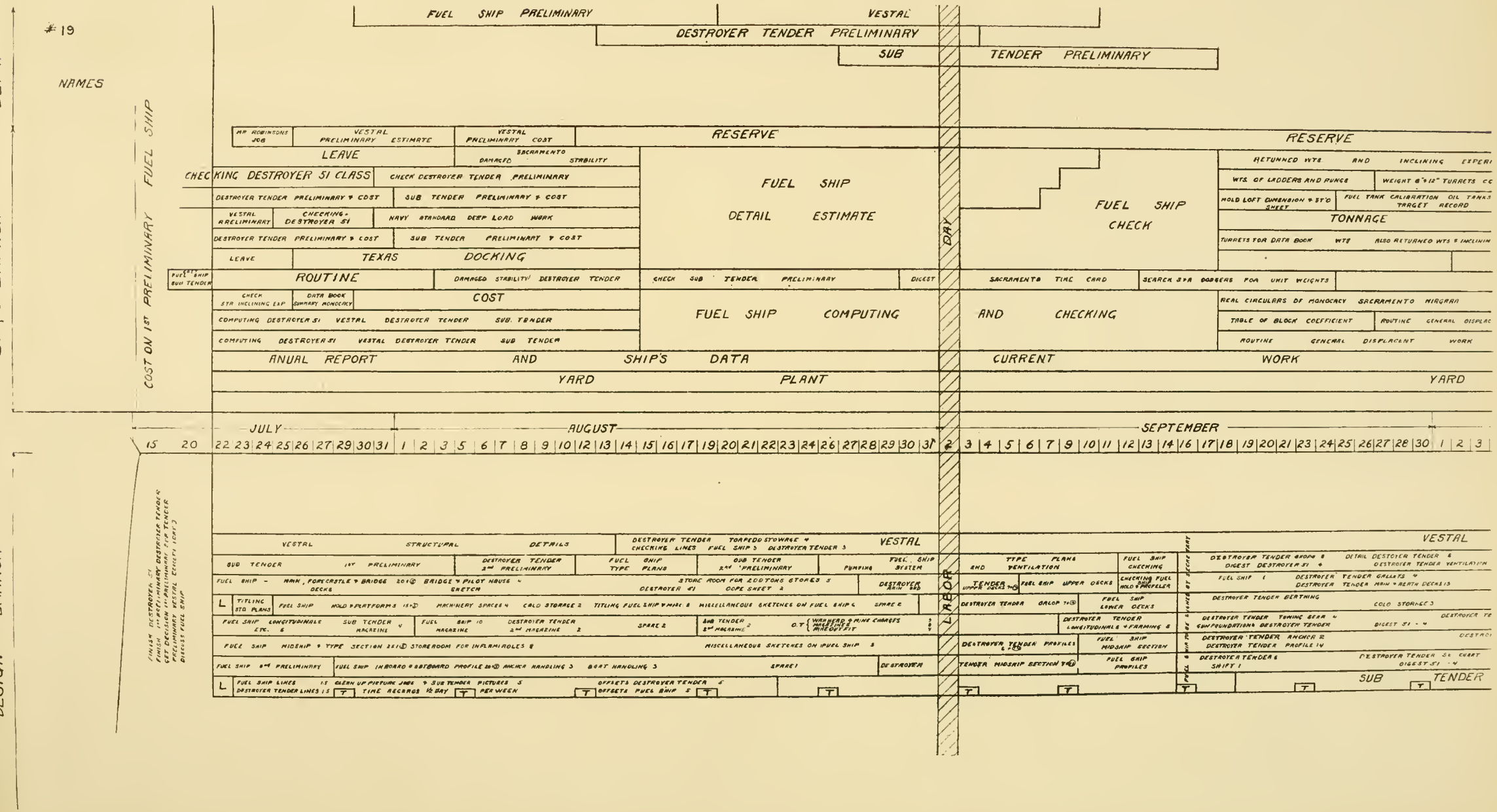
To illustrate paper on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. Navy, Member.

THE SCIENTIFIC AND COMPUTING BRANCH.

To illustrate paper on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. Navy, Member.



To illustrate paper on "The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department," by Naval Constructor R. H. Robinson, U. S. Navy, Member.



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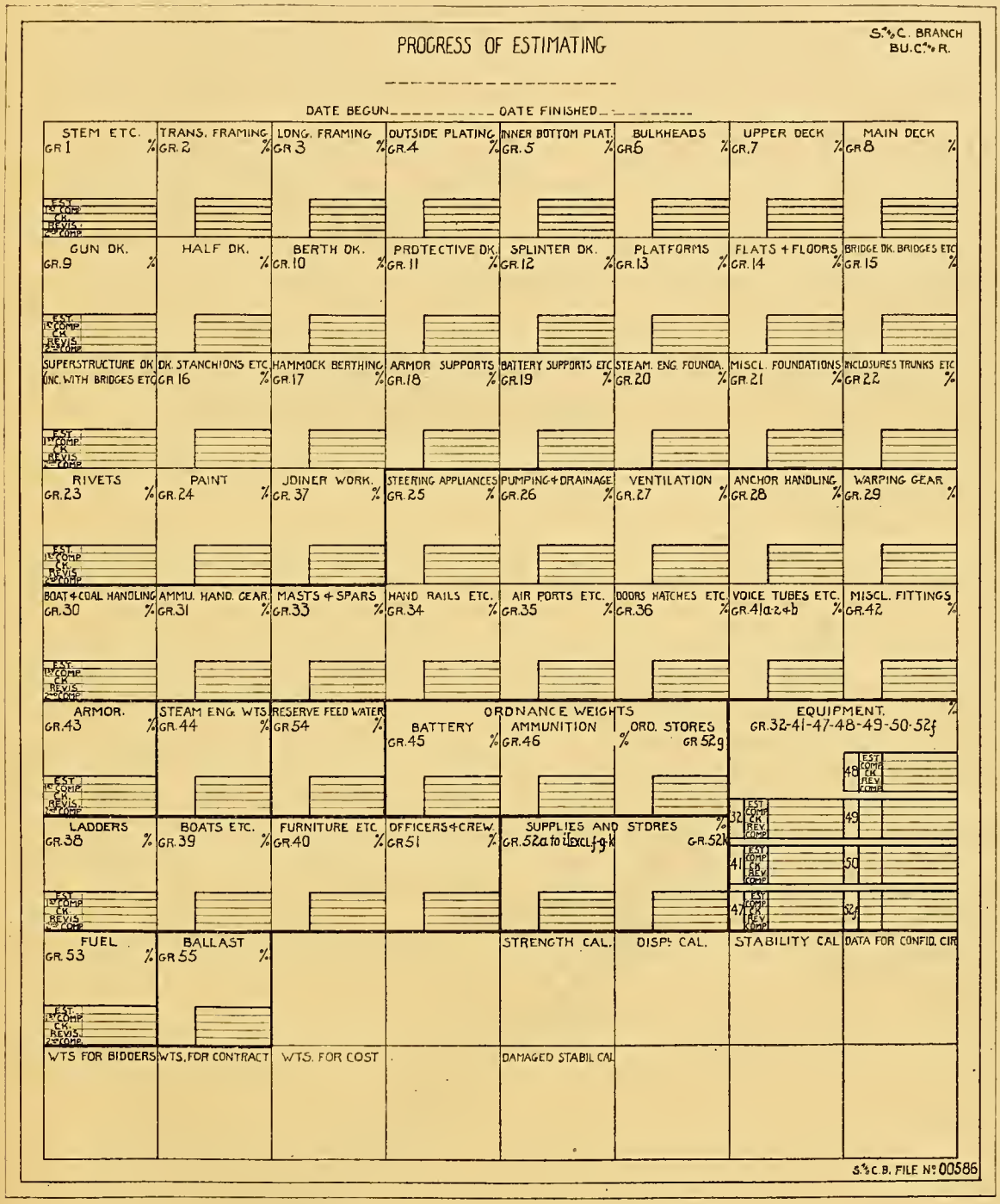
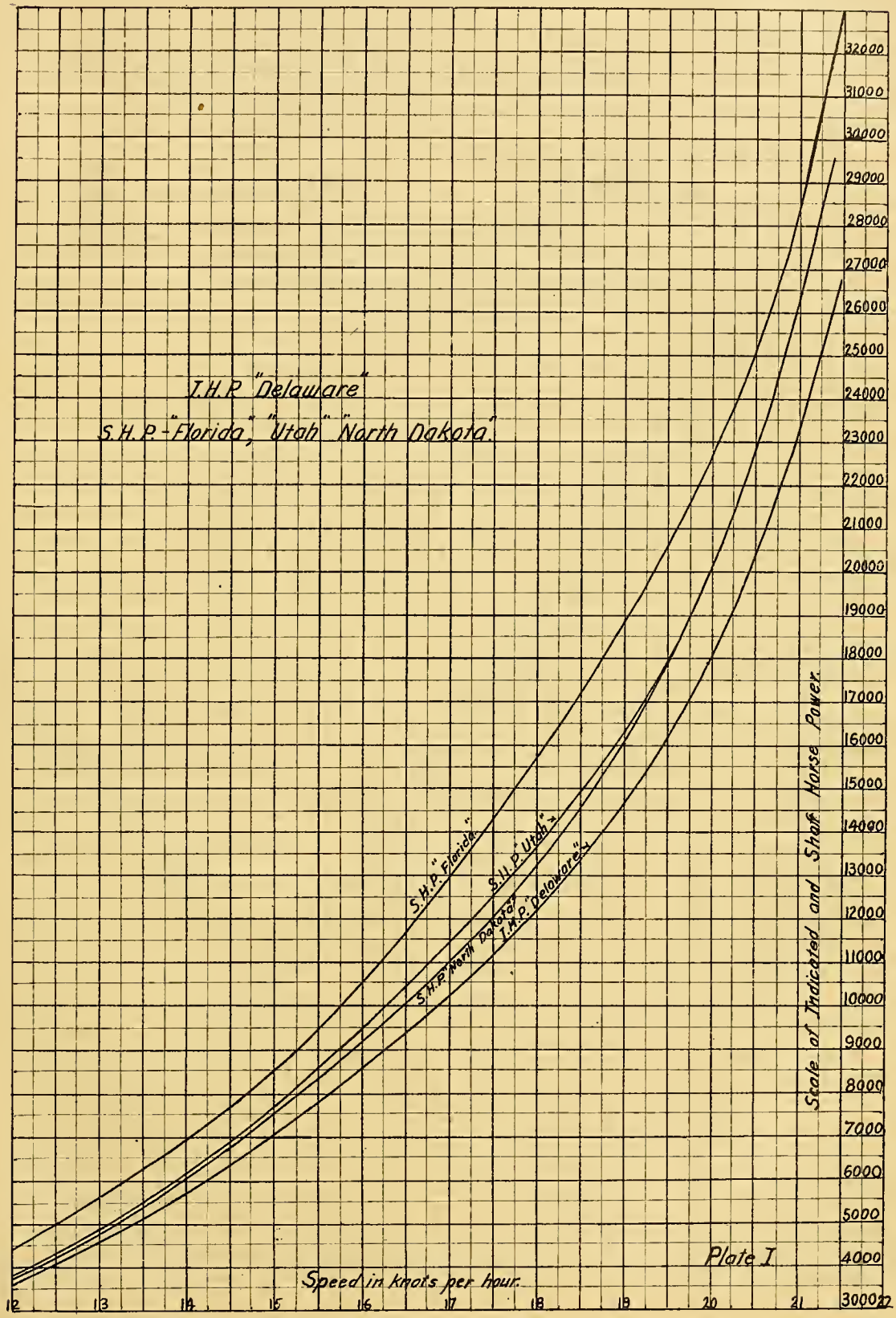


To illustrate paper on "Engineering Progress in the United States Navy," by Captain C. W. Dyson, U. S. N.



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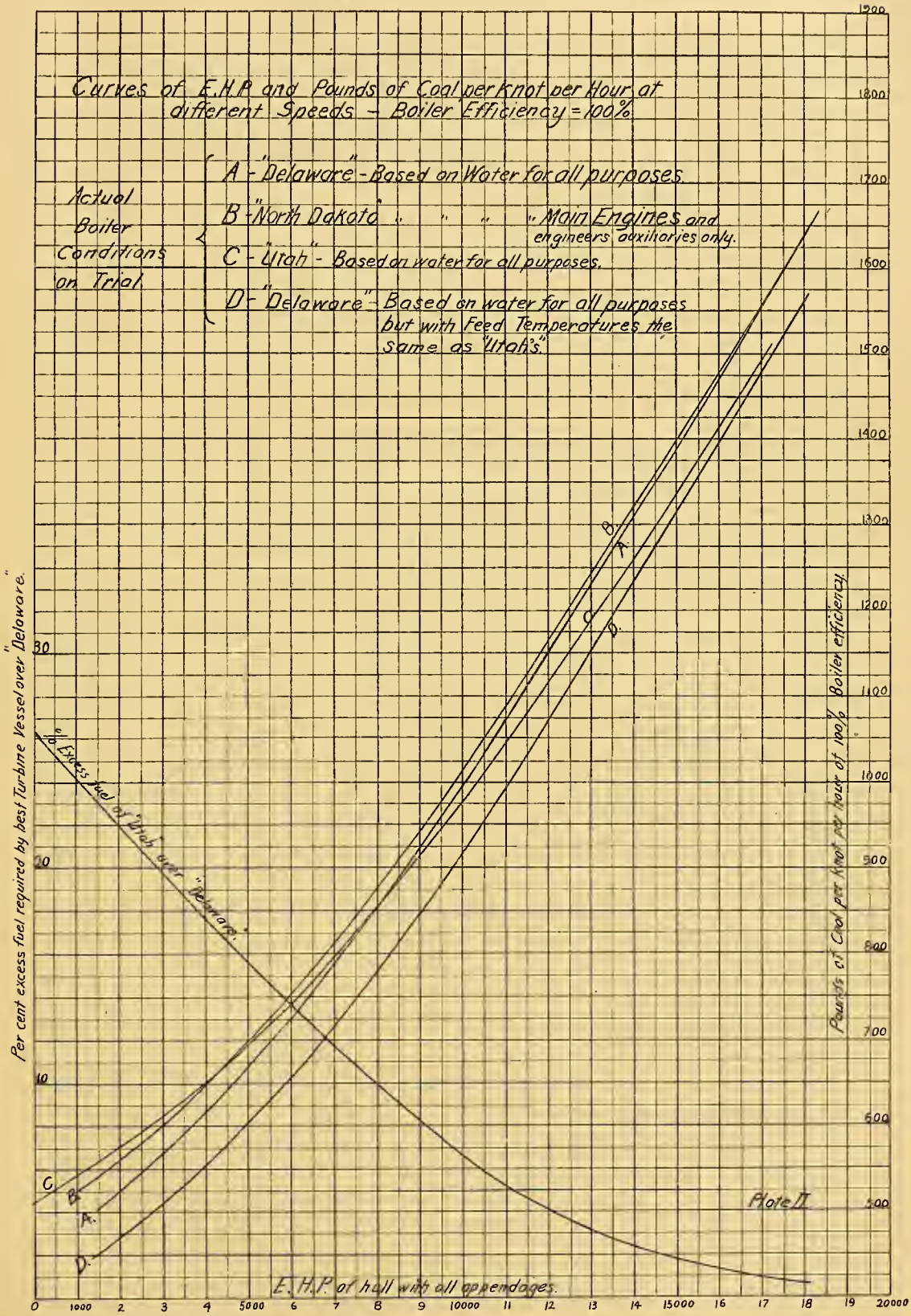

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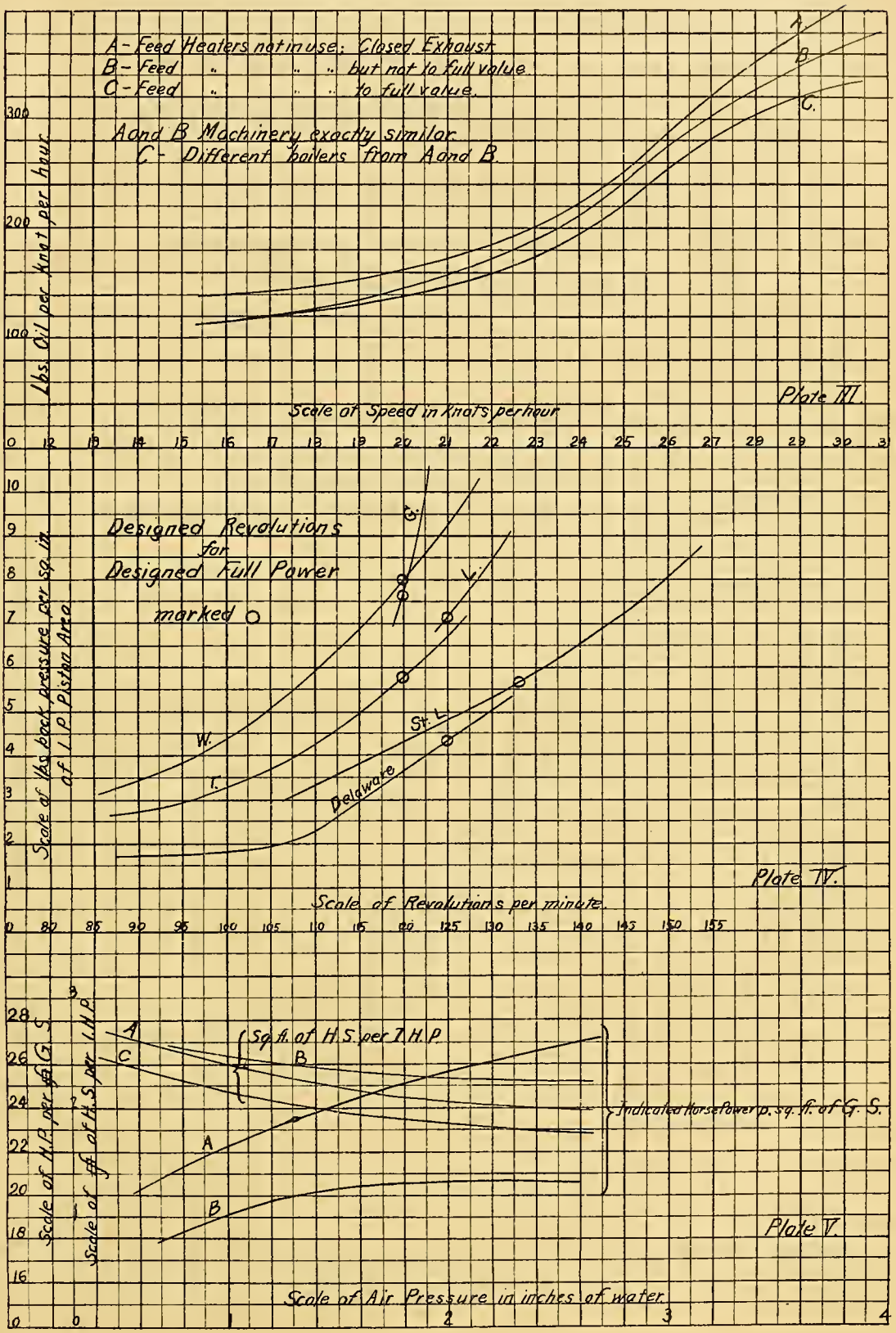

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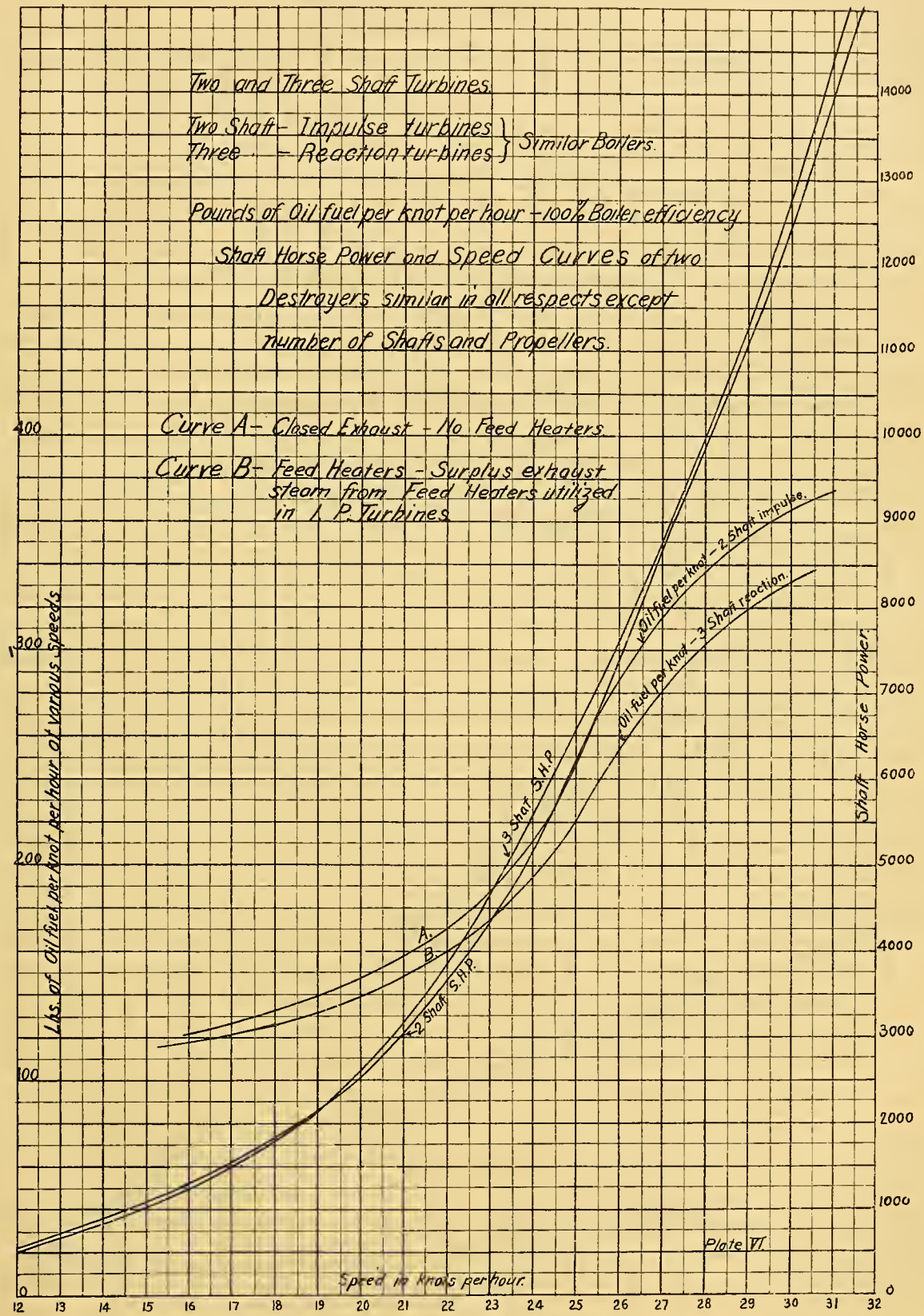

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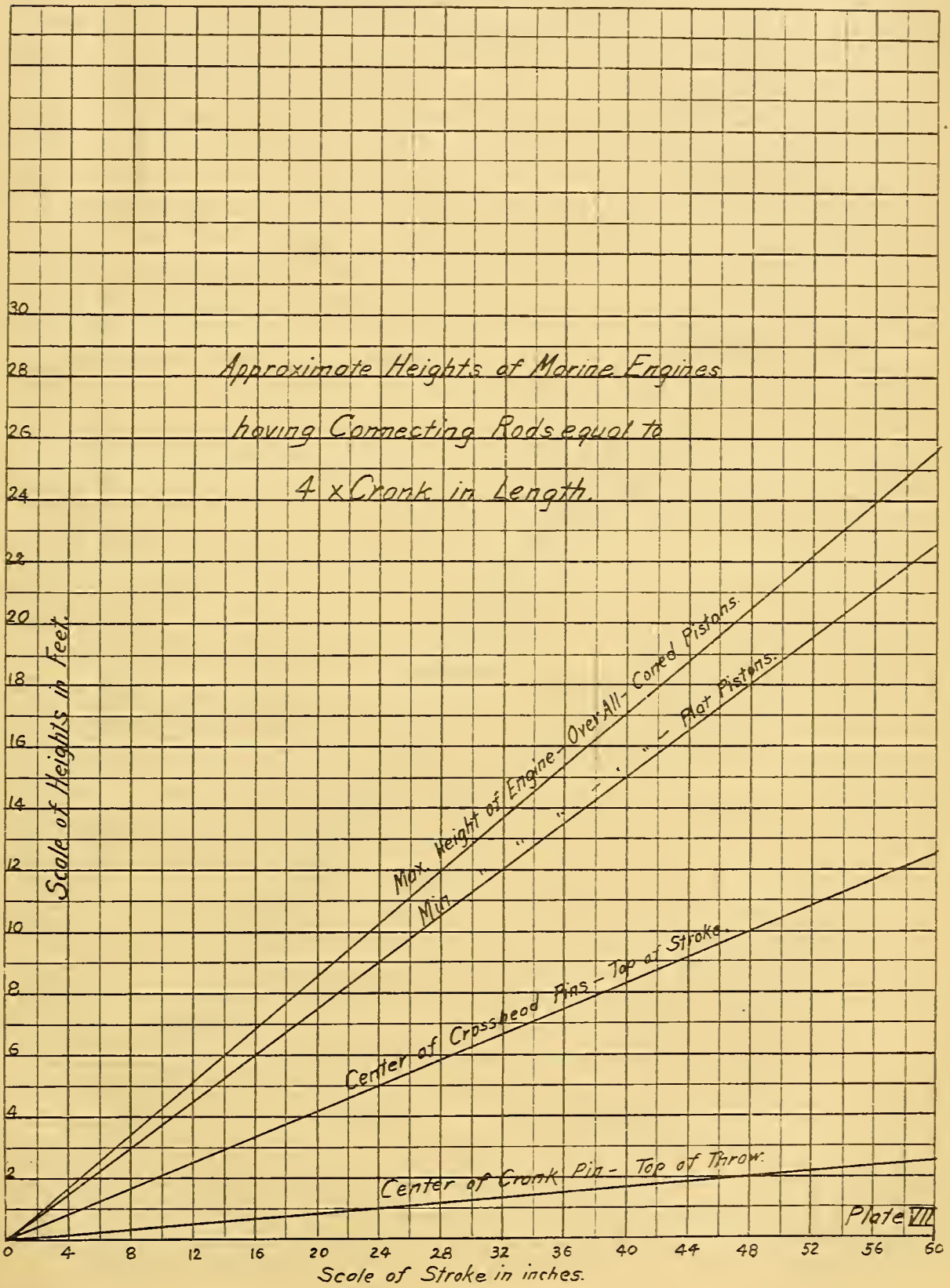

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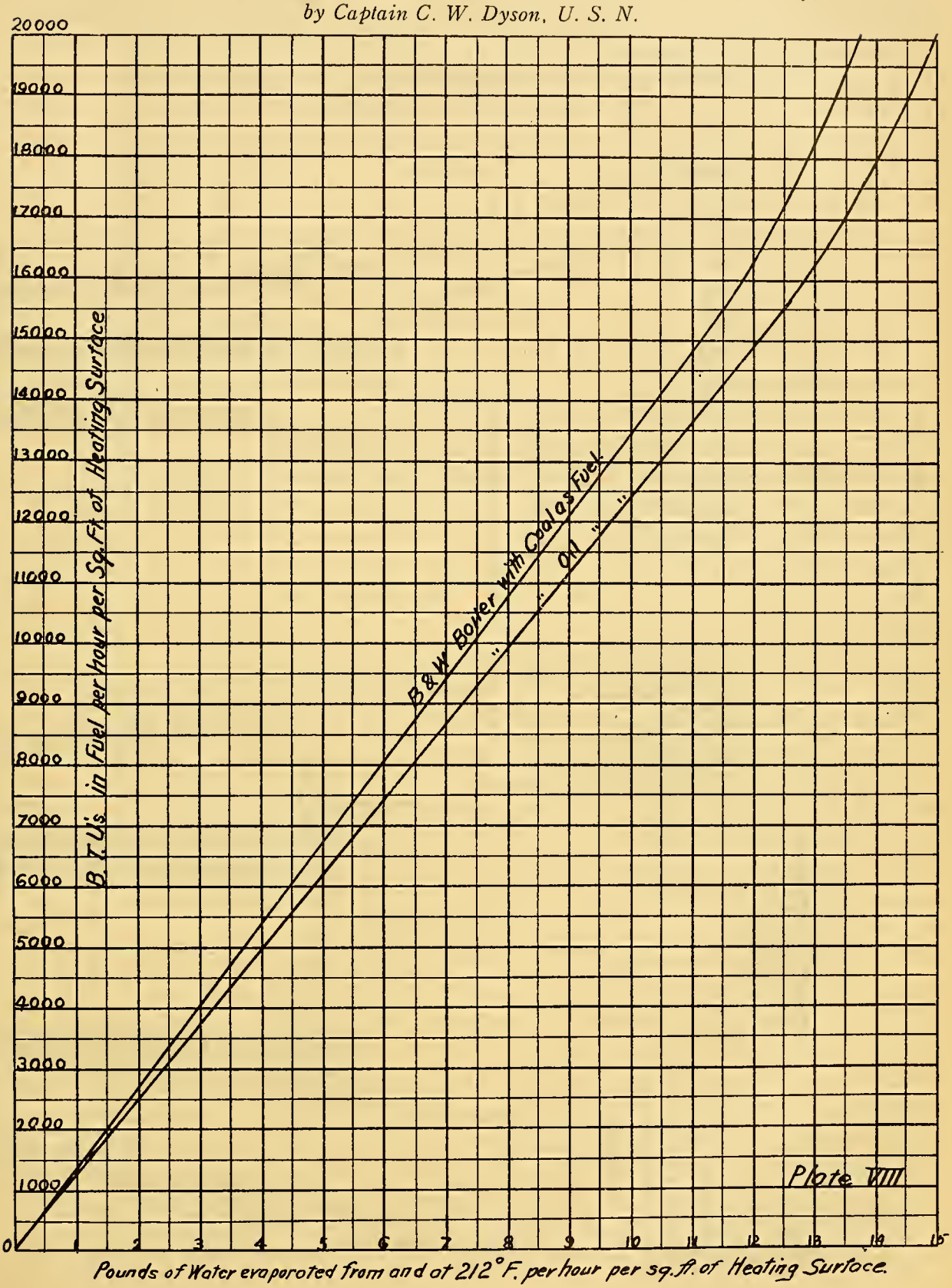
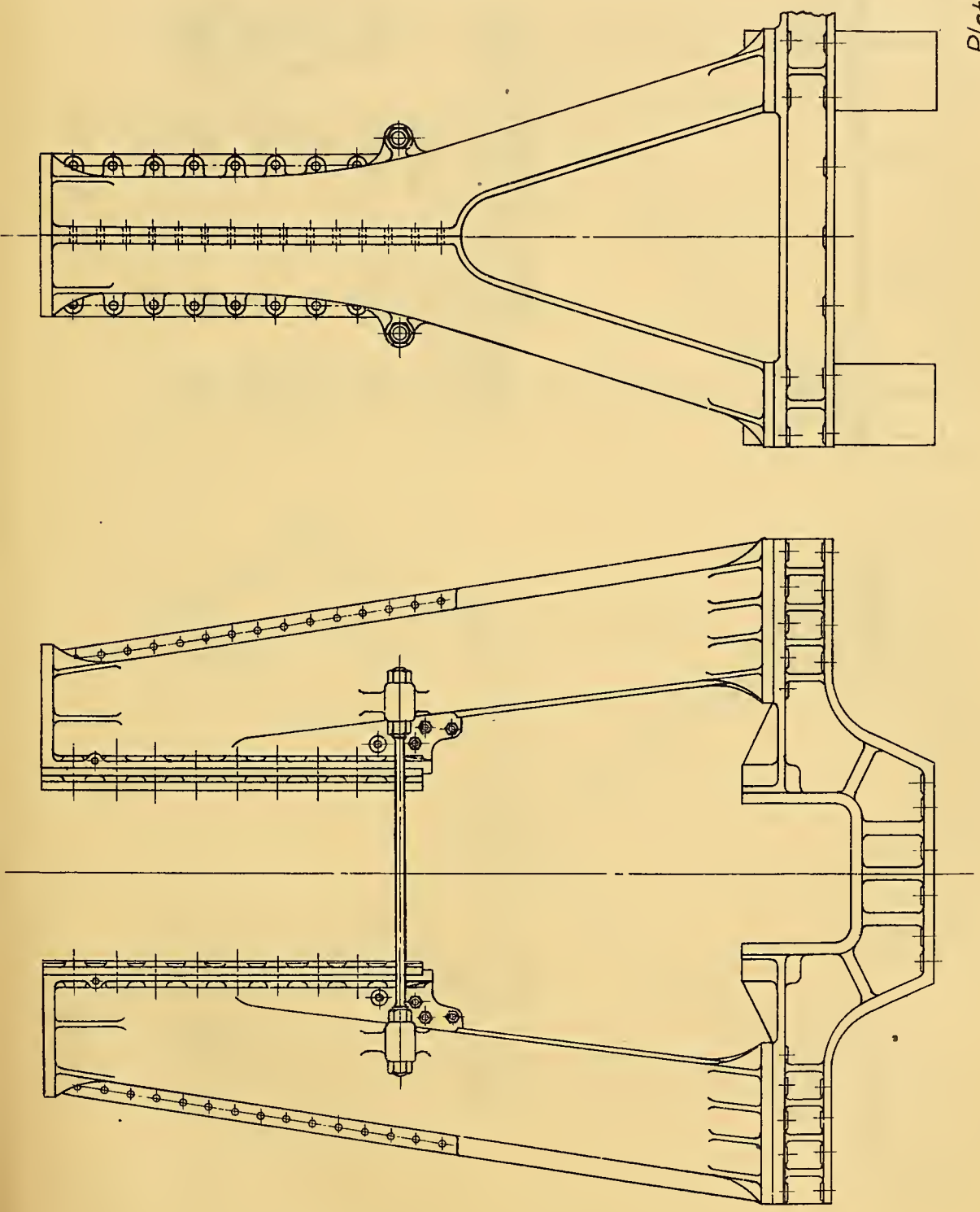


To illustrate paper on "Engineering Progress in the United States Navy," by Captain C. W. Dyson, U. S. N.

Plate IX.



U.S.S. BROOKLYN.

Cast Steel Engine Framing.

To illustrate paper on "Engineering Progress in the United States Navy," by Captain C. W. Dyson, U. S. N.

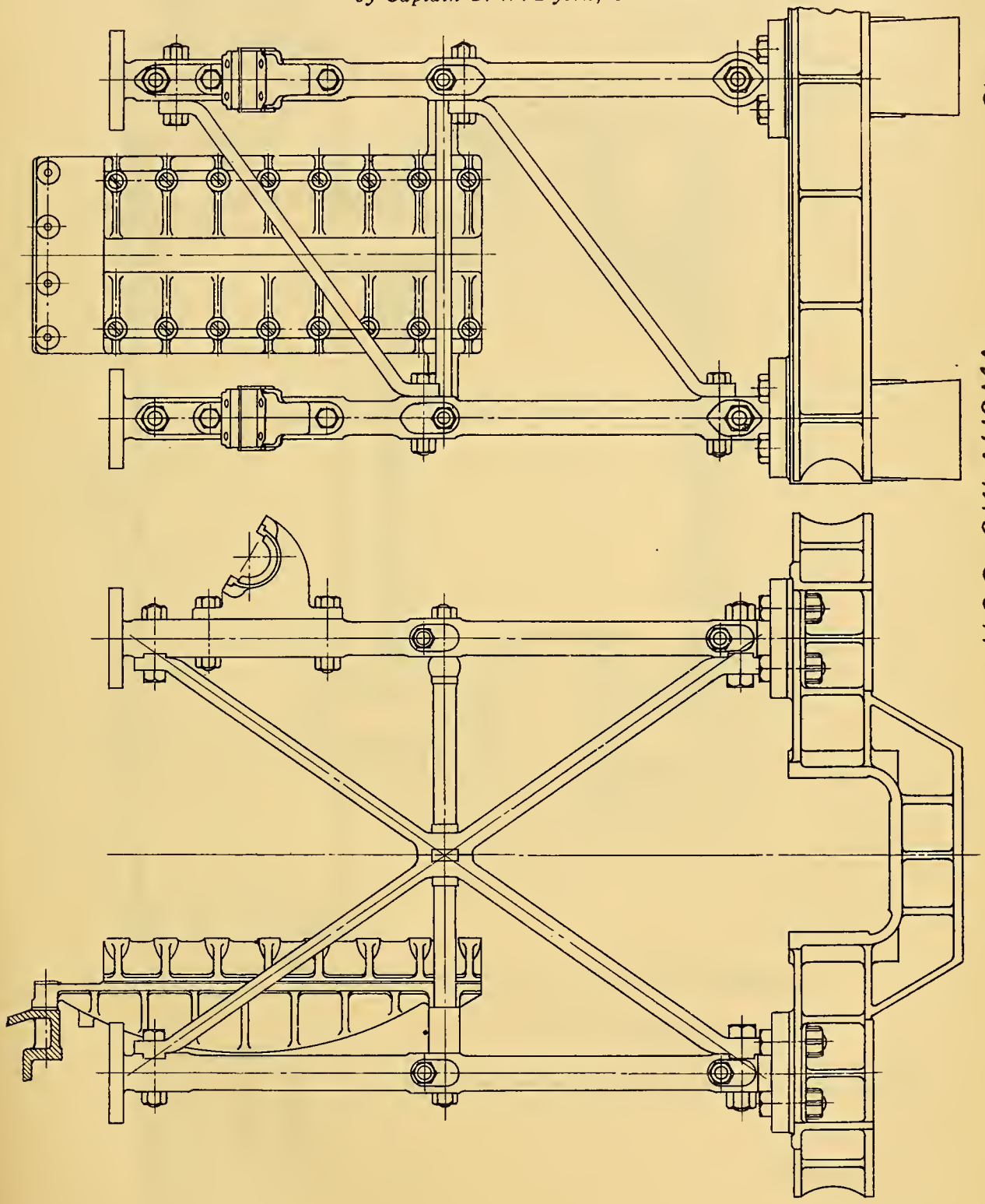
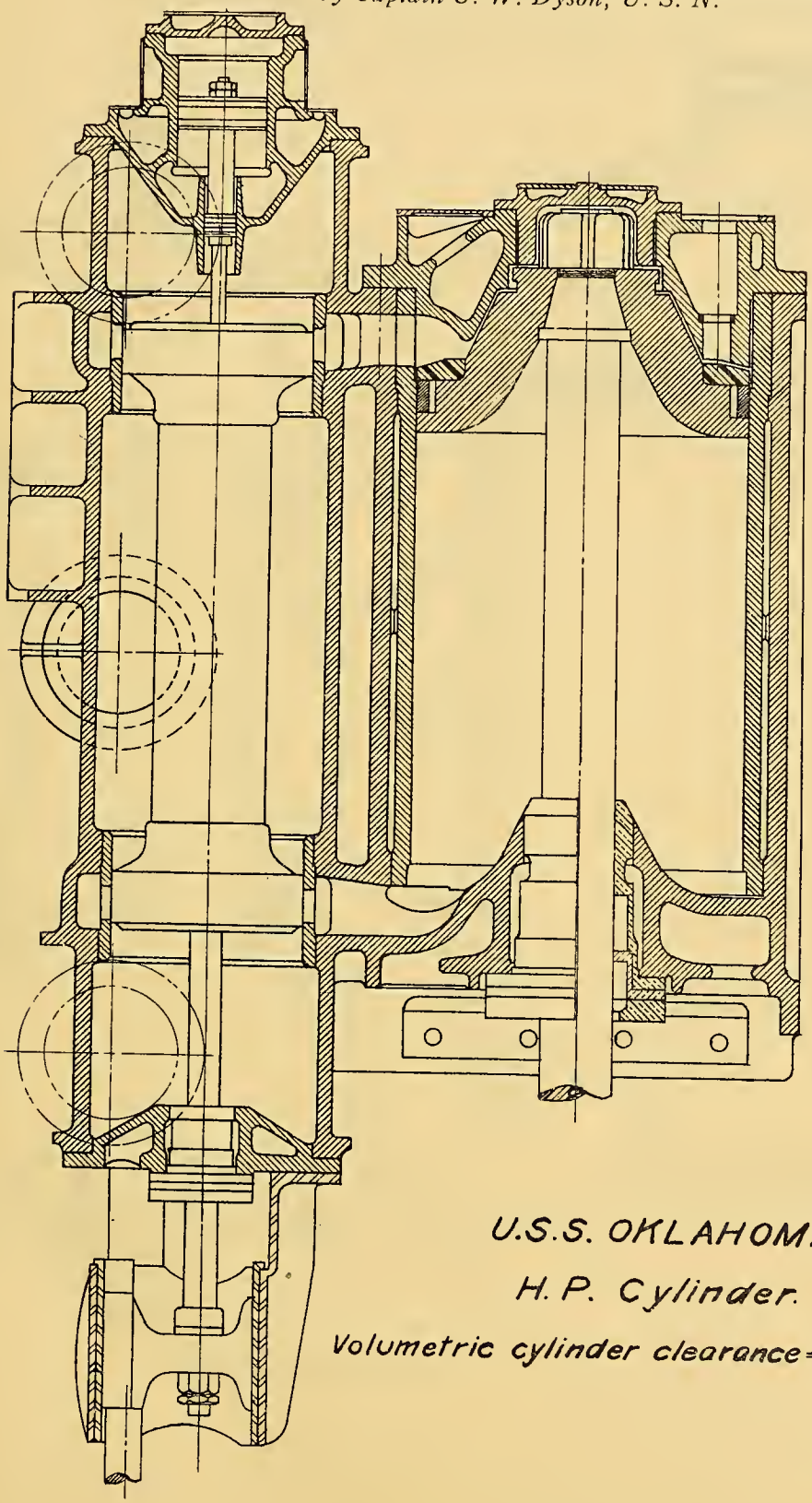


Plate X.

U.S.S. OKLAHOMA.

Forged Steel Engine Framing

To illustrate paper on "Engineering Progress in the United States Navy," by Captain C. W. Dyson, U. S. N.



U.S.S. OKLAHOMA.

H. P. Cylinder.

Volumetric cylinder clearance = 10.75% (mean)

Plate XI.

To illustrate paper on "Engineering Progress in the United States Navy," by Captain C. W. Dyson, U. S. N.

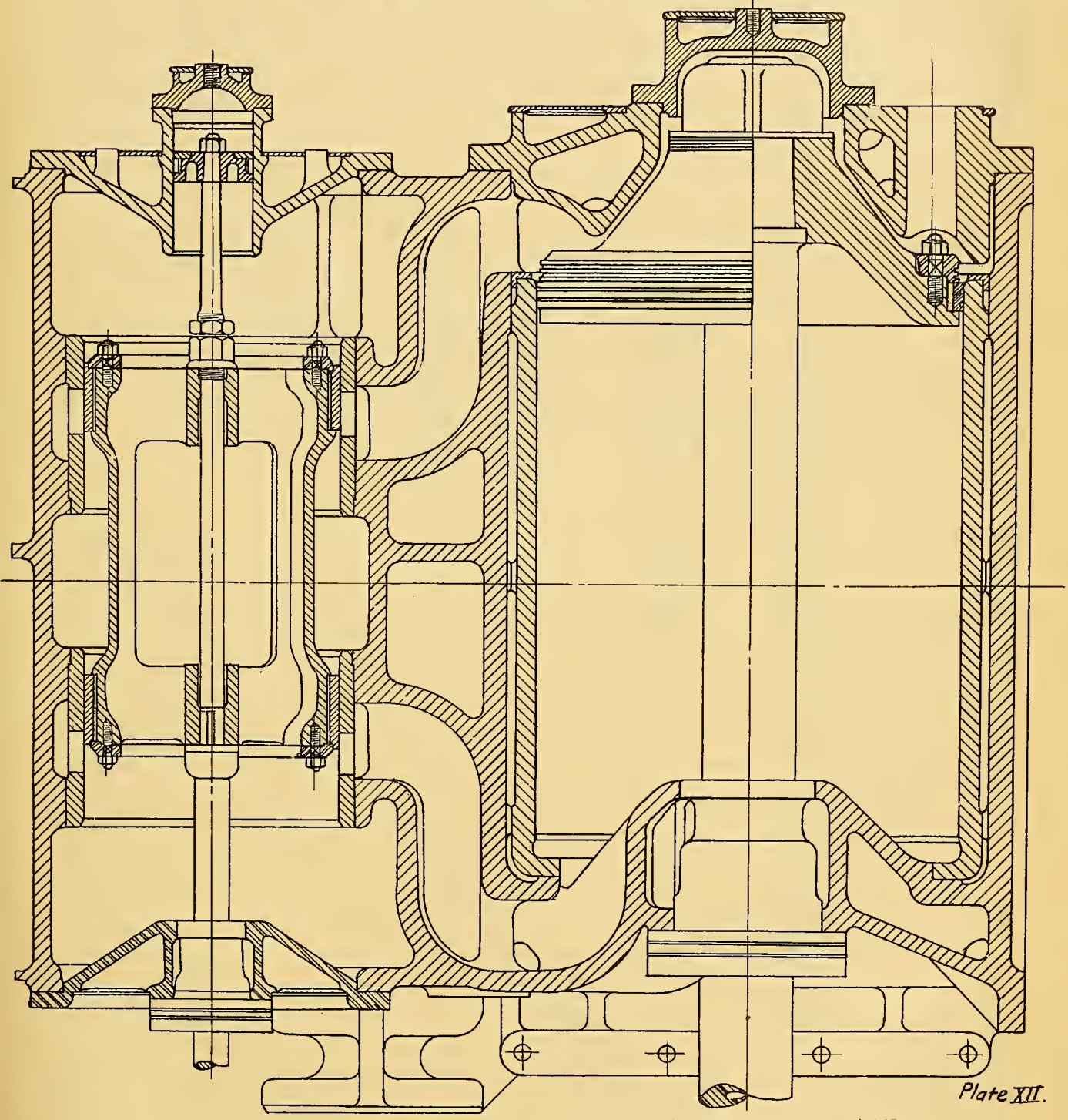
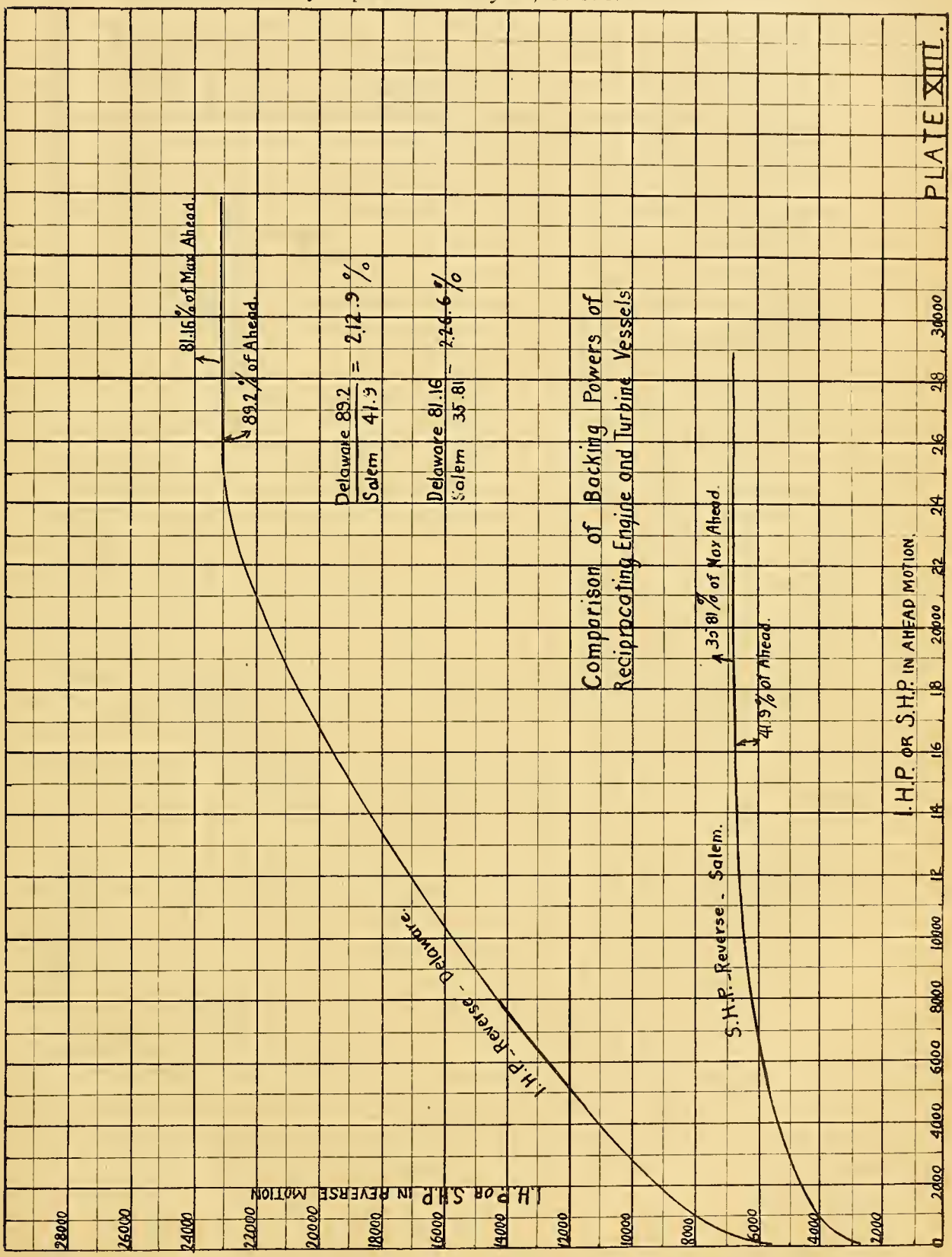


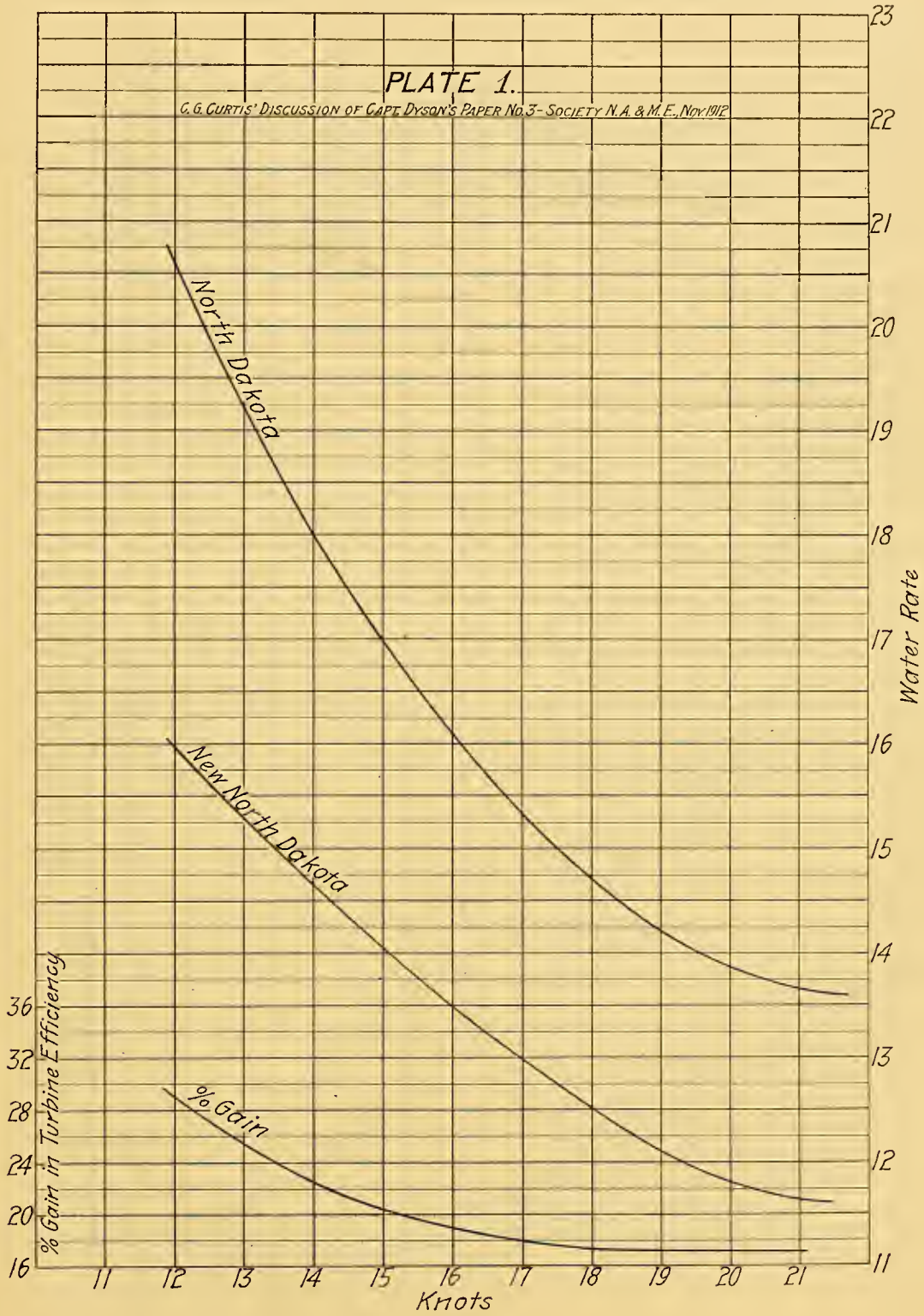
Plate XII.

U.S.S. MARYLAND.
H.P. Cylinder.
Volumetric cylinder clearance=27% (mean)

To illustrate paper on "Engineering Progress in the United States Navy," by Captain C. W. Dyson, U. S. N



To illustrate discussion by Charles G. Curtis, Esq., Member, on paper entitled "Engineering Progress in the U. S. Navy," by Captain C. W. Dyson, U. S. N.



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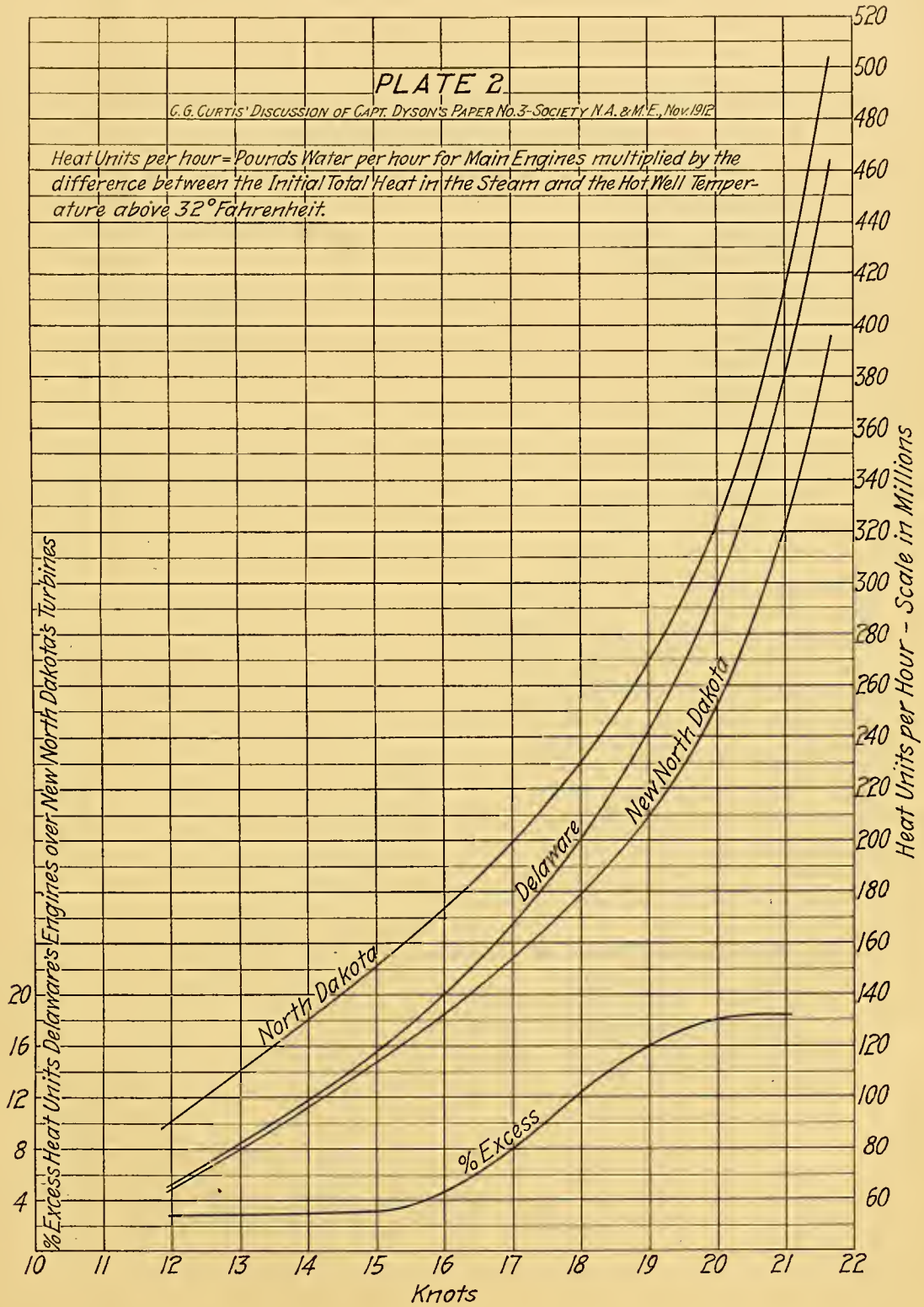
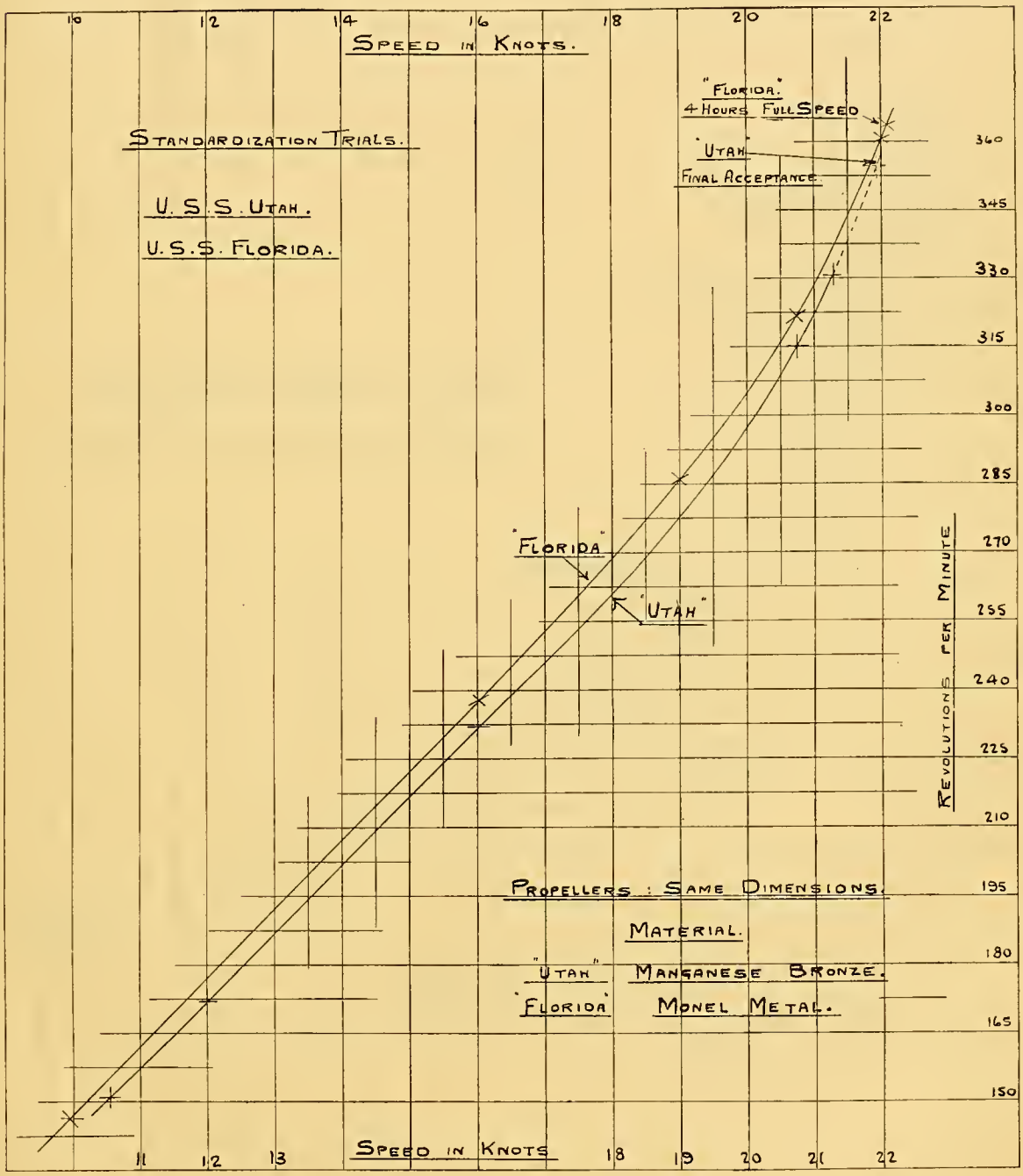
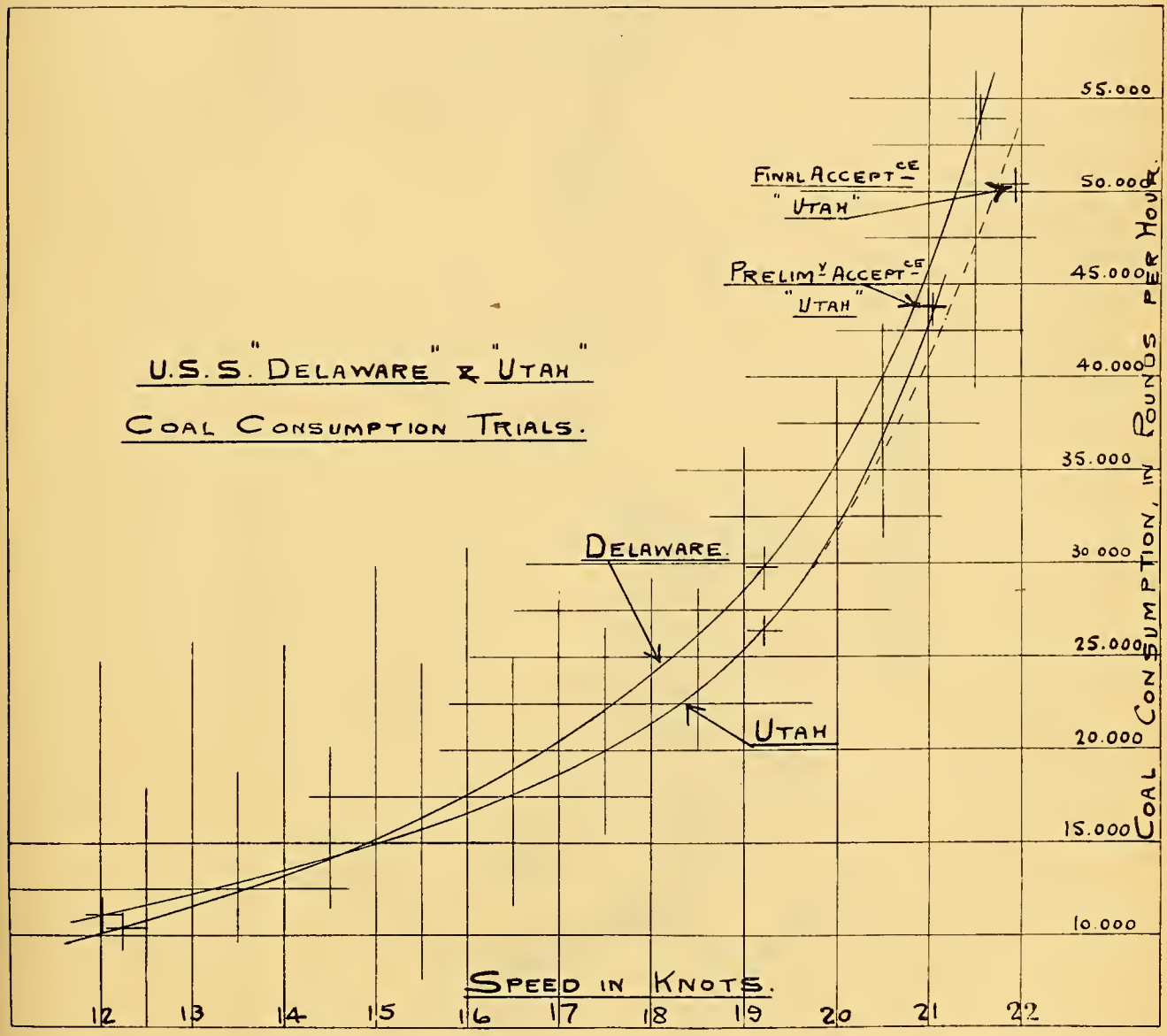


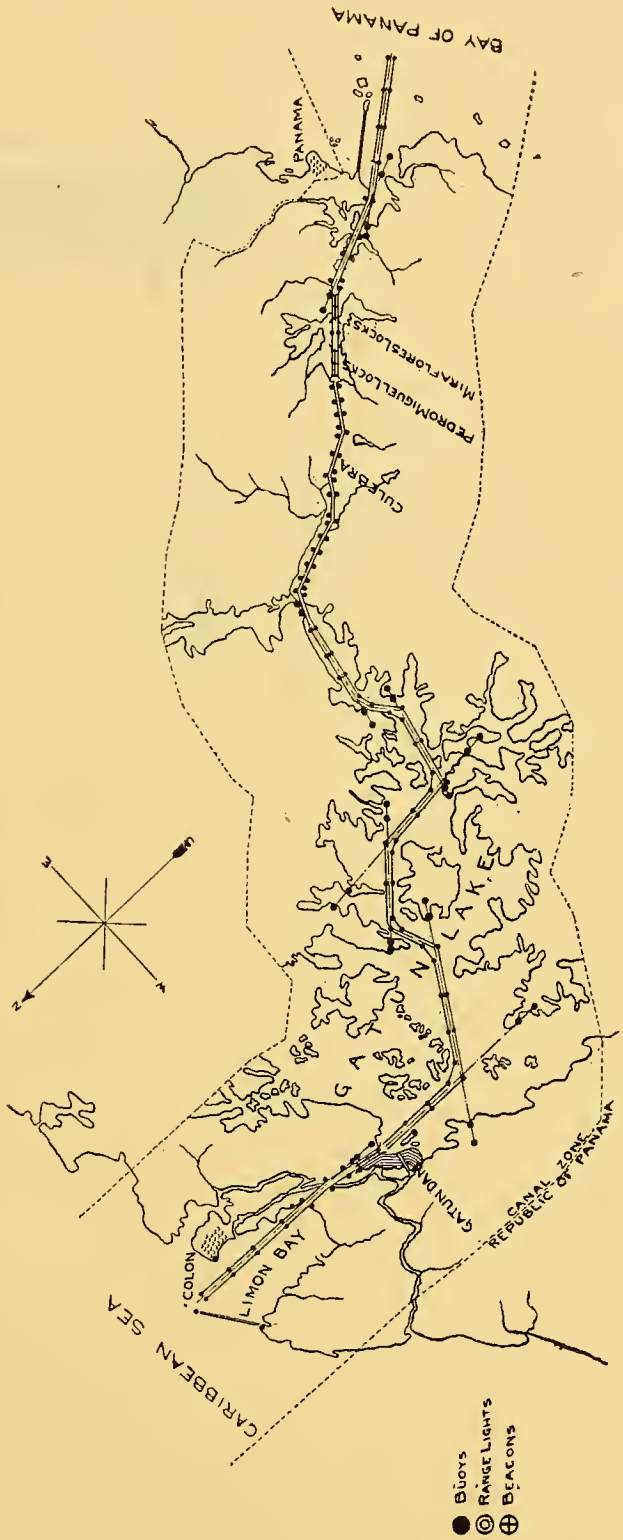
To illustrate discussion by E. H. B. Anderson, Esq., Member, on paper entitled "Engineering Progress in the U. S. Navy," by Captain C. W. Dyson, U. S. N.



To illustrate discussion by E. H. B. Anderson, Esq., Member, on paper entitled "Engineering Progress in the U. S. Navy," by Captain C. W. Dyson, U. S. N.

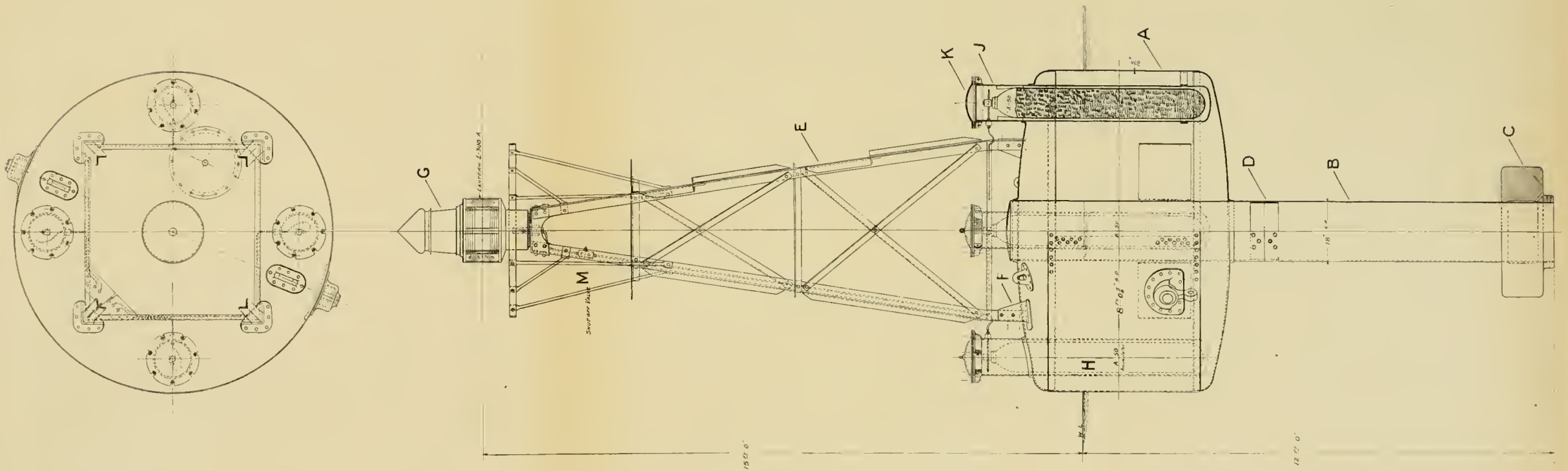


To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



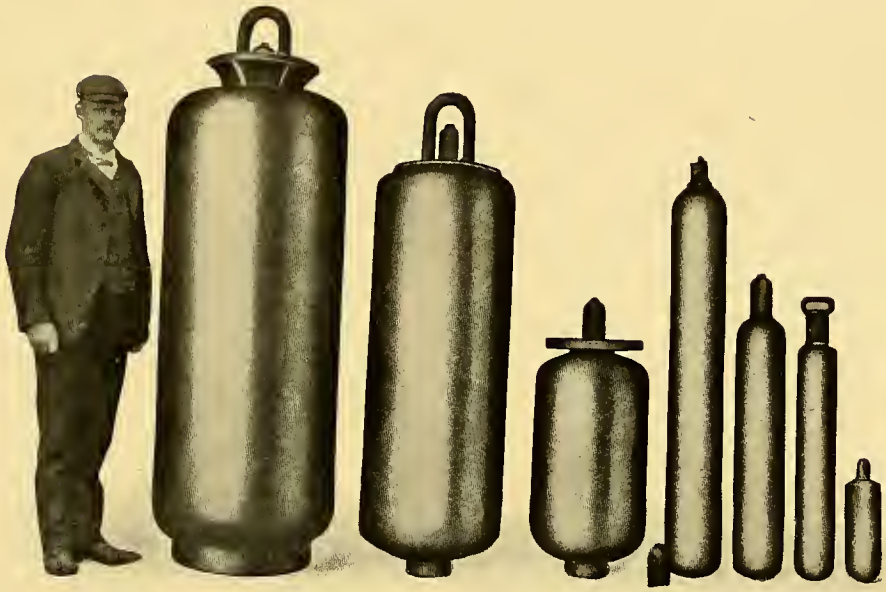
PANAMA CANAL
SHOWING LOCATION OF LIGHTS.

To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



Light Buoy. Weight, 10,500 Pounds. Pendular Period, 5.3 Seconds.

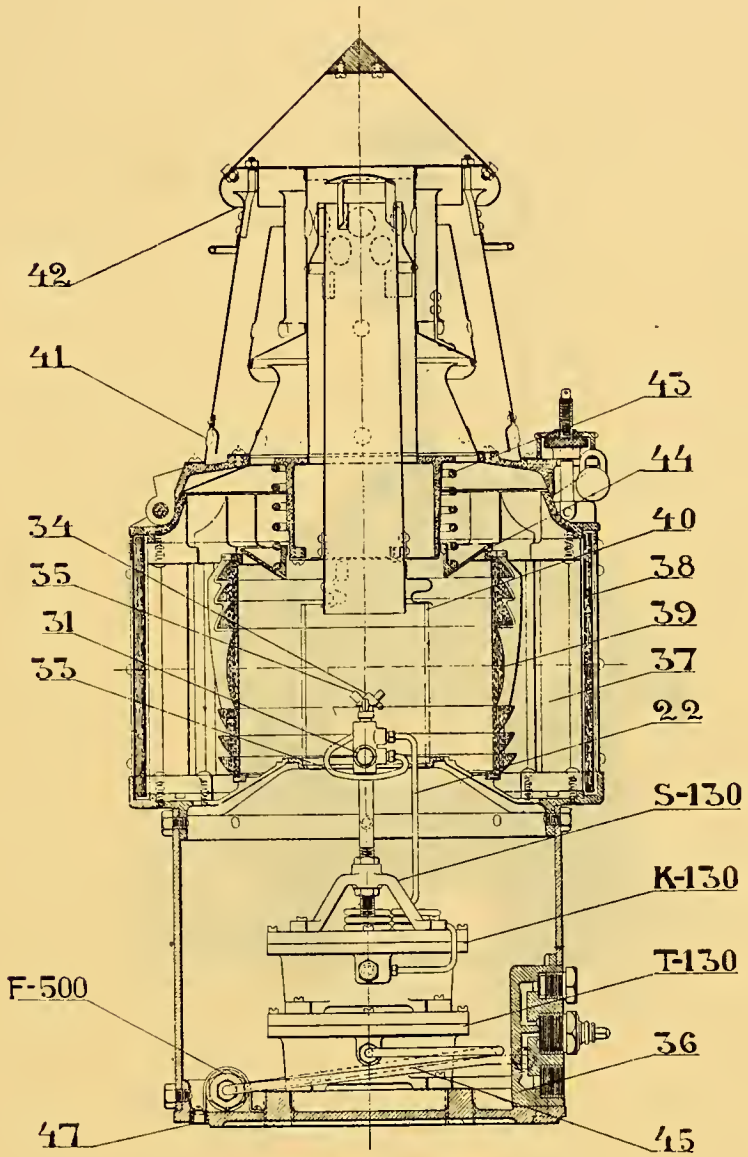
To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



A-600 A W-300 A-50 A-25

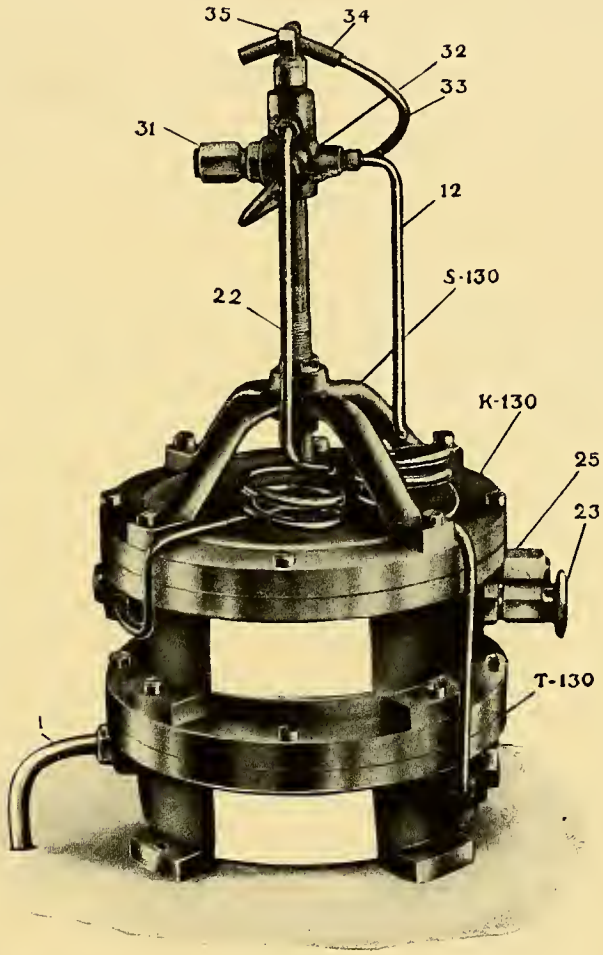
TYPES OF ACCUMULATORS.

To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



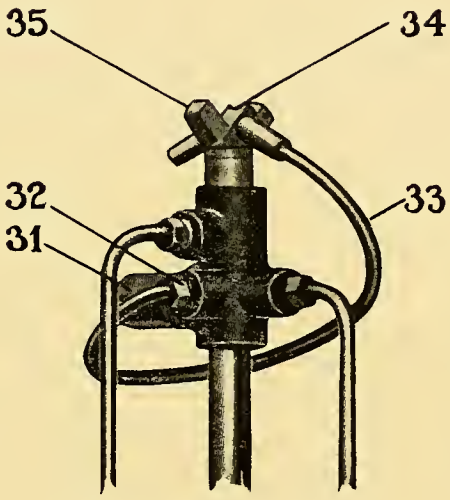
BUOY LANTERN.

To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



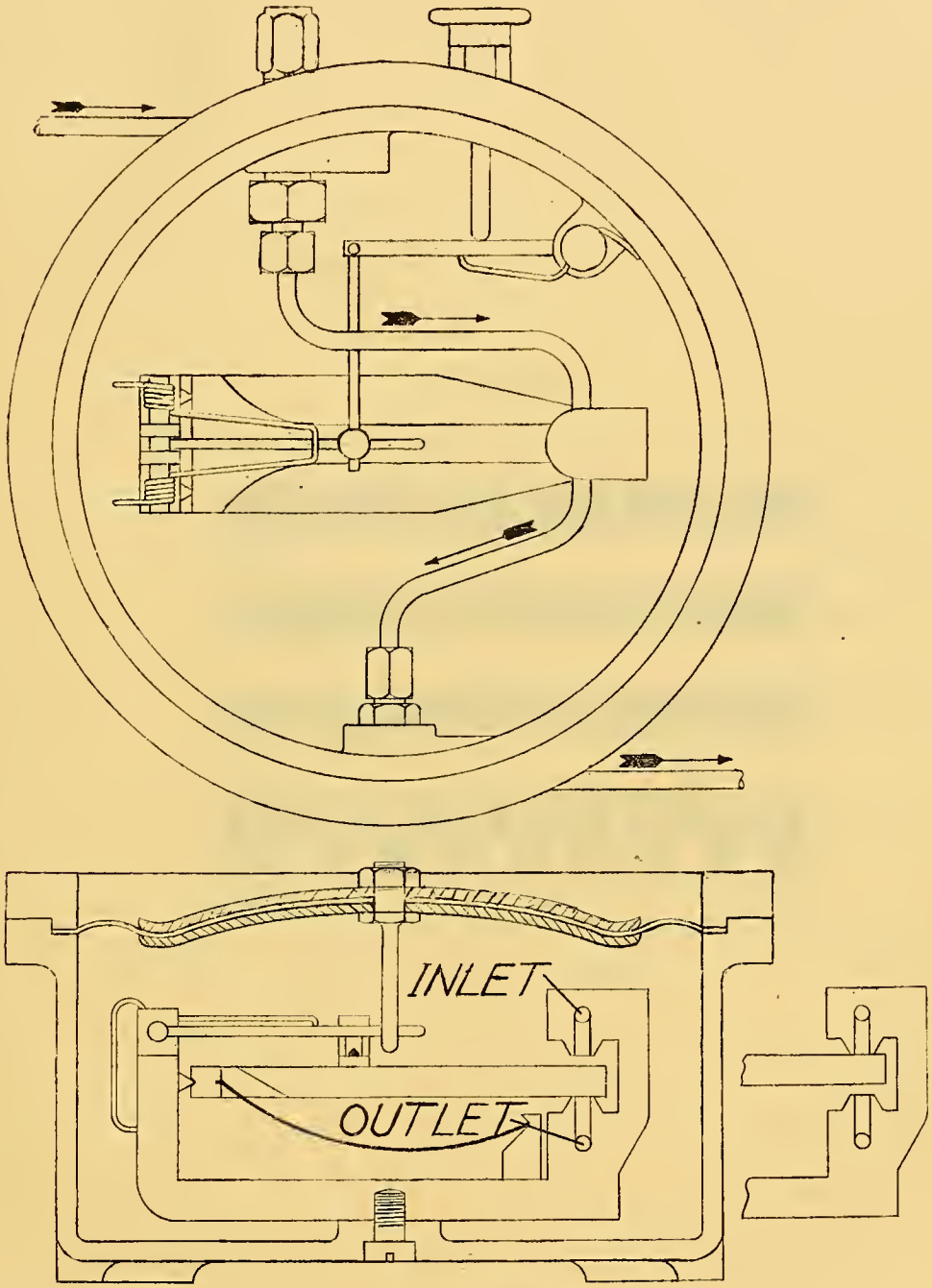
FLASHER.

To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



BURNER WITH PILOT BURNER.

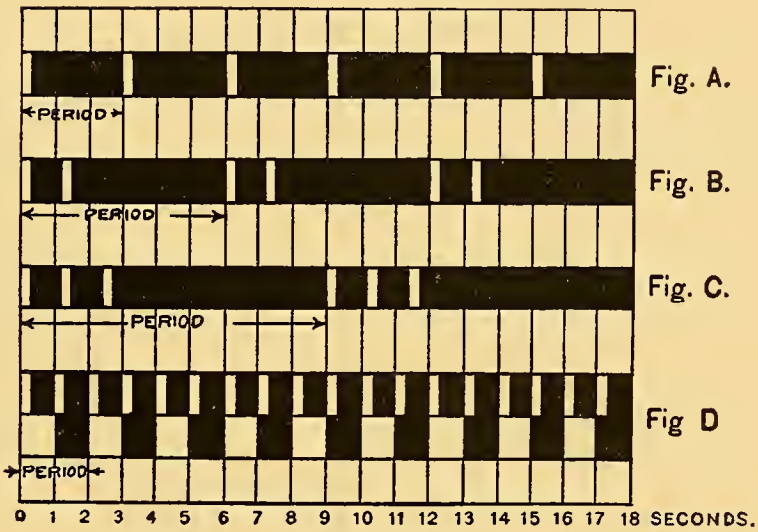
To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



THE FLASHER.

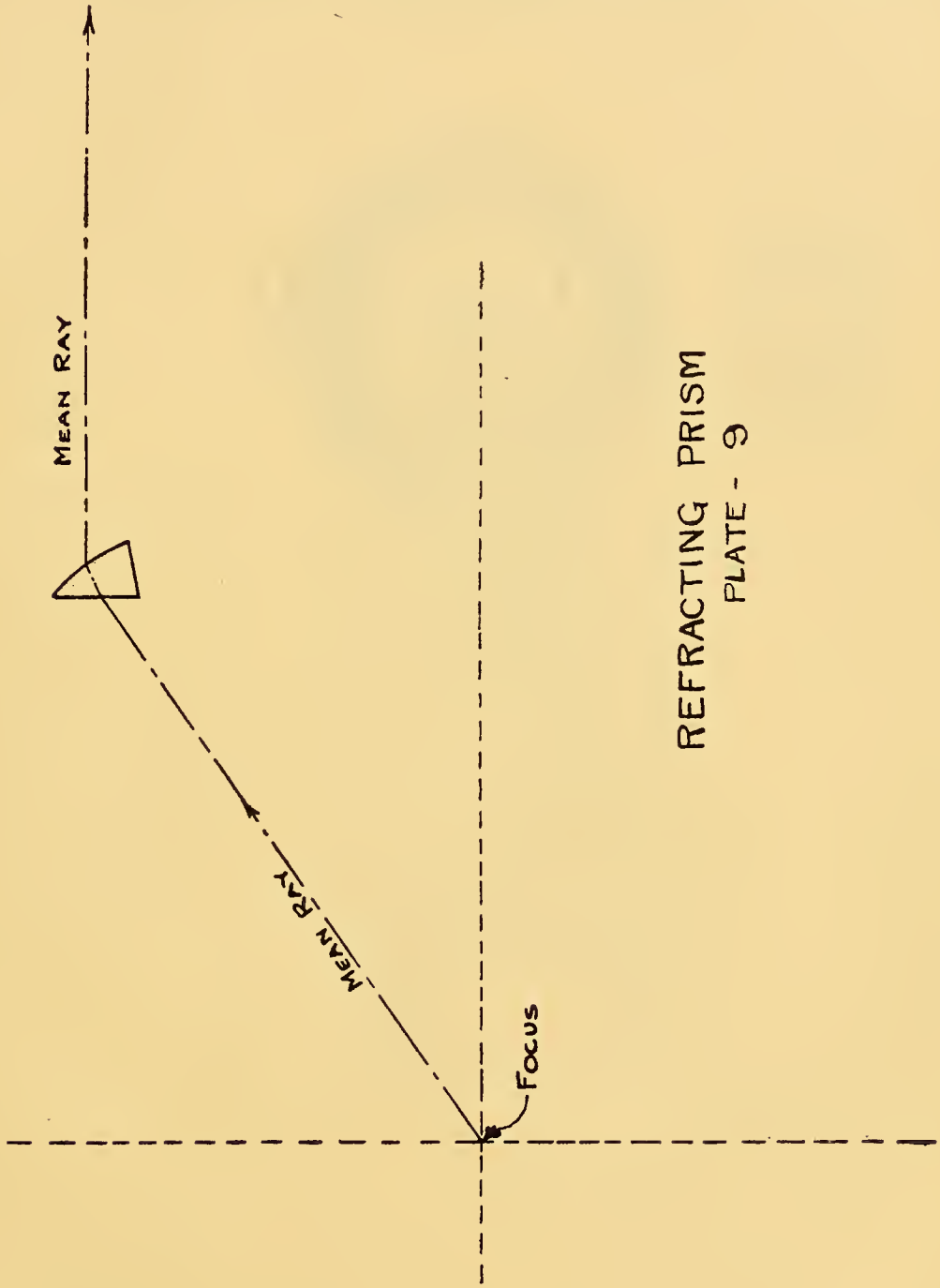
To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.

Diagram 1.



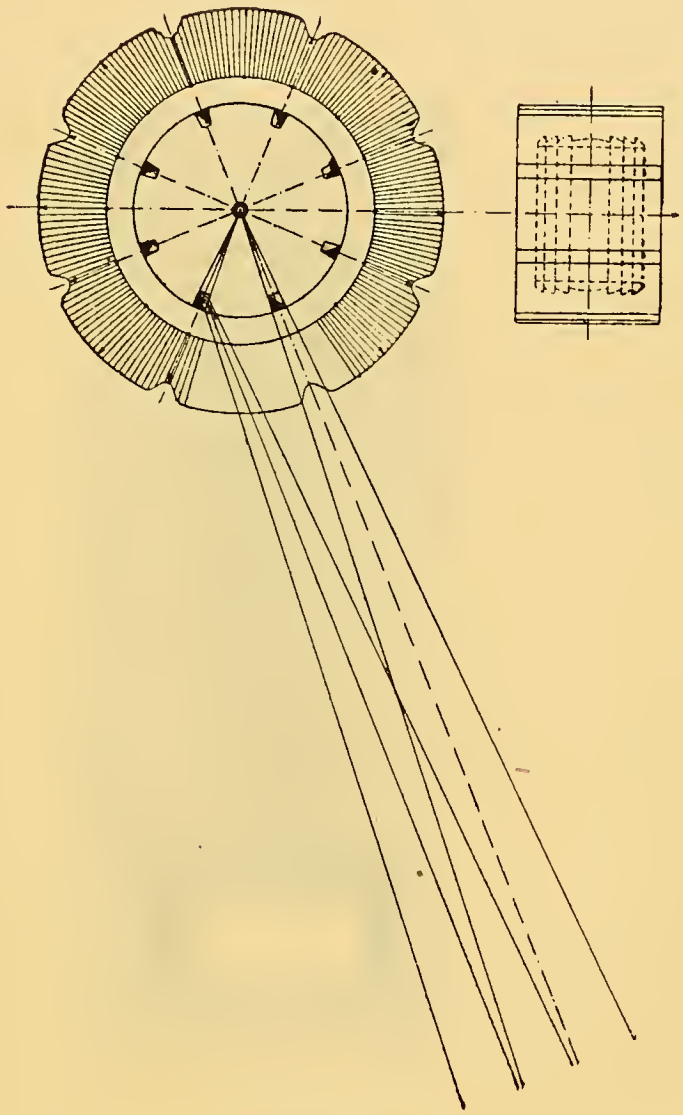
Light Characters.

To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



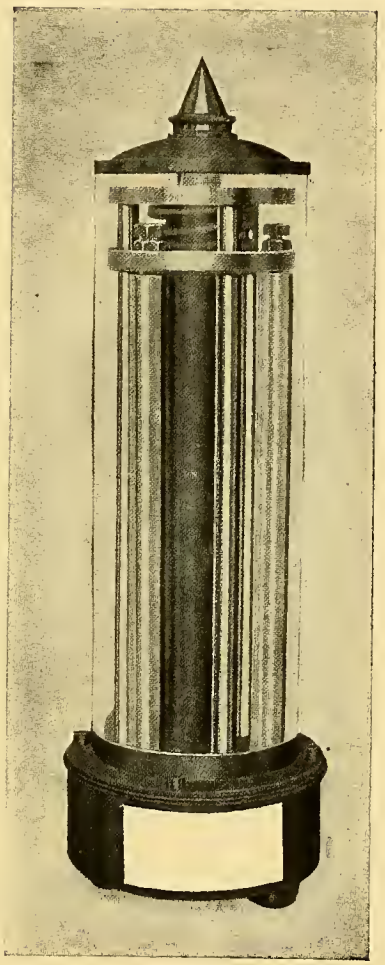
REFRACTING PRISM
PLATE - 9

To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



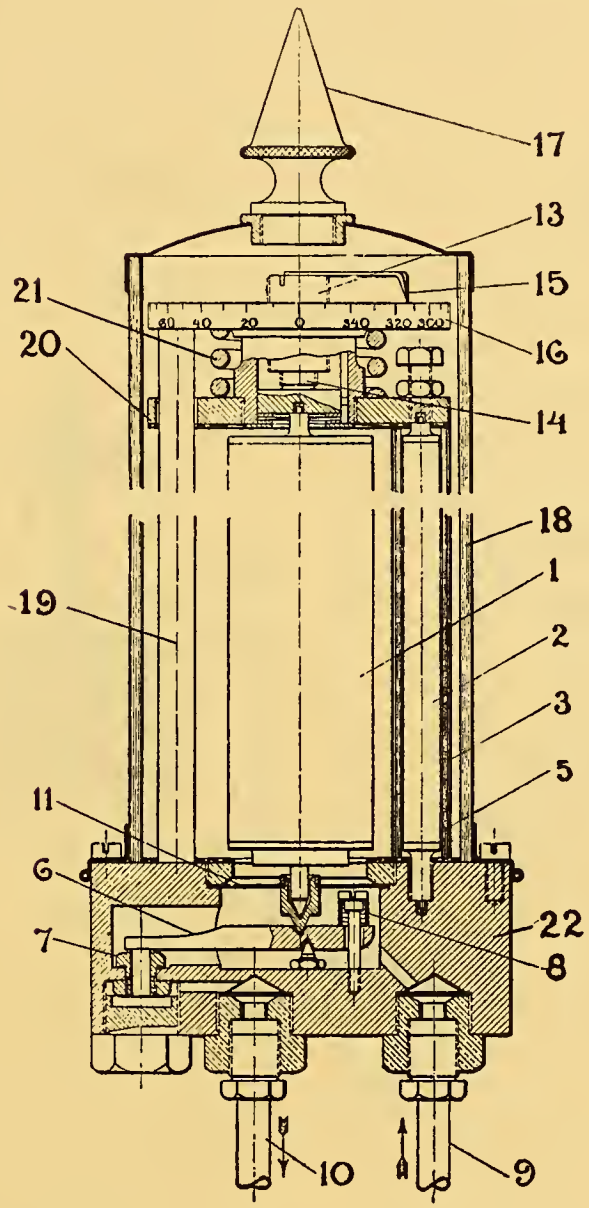
REFLECTING PRISMS.

To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.

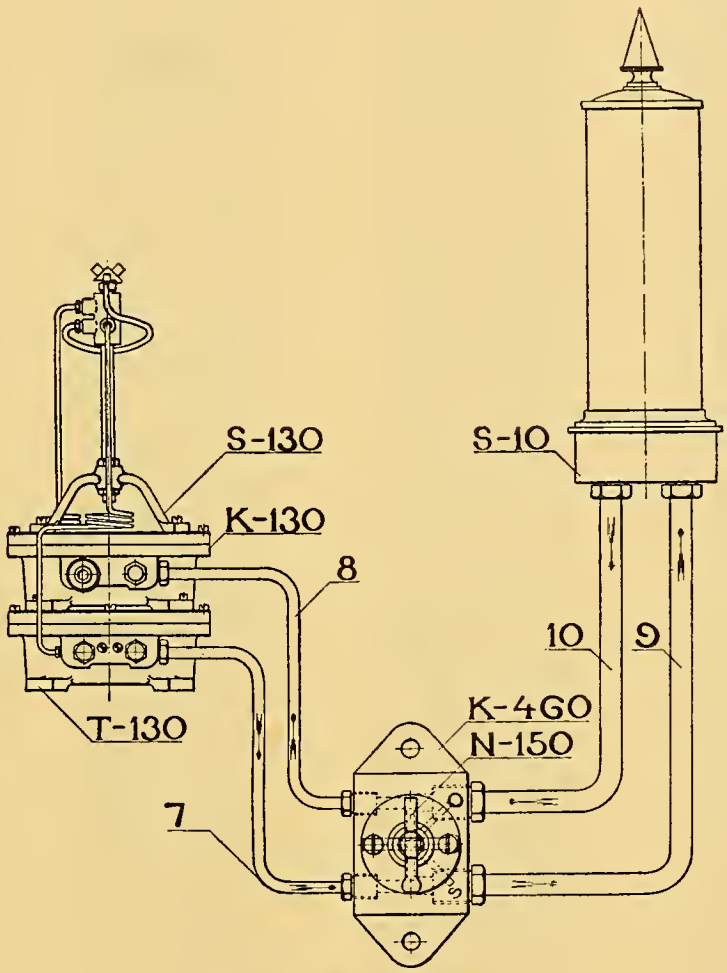


SUNVALVE.

To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.

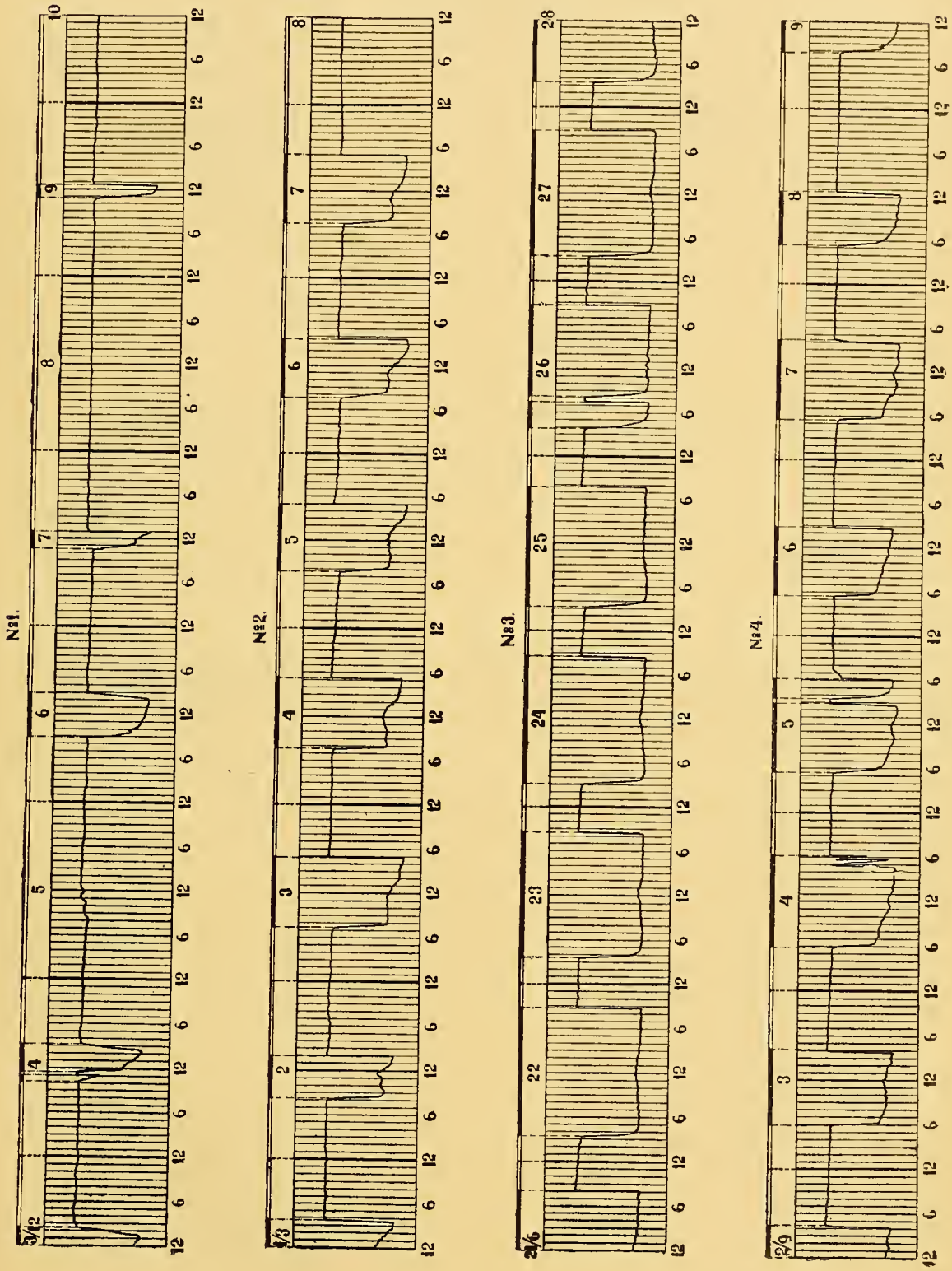


To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



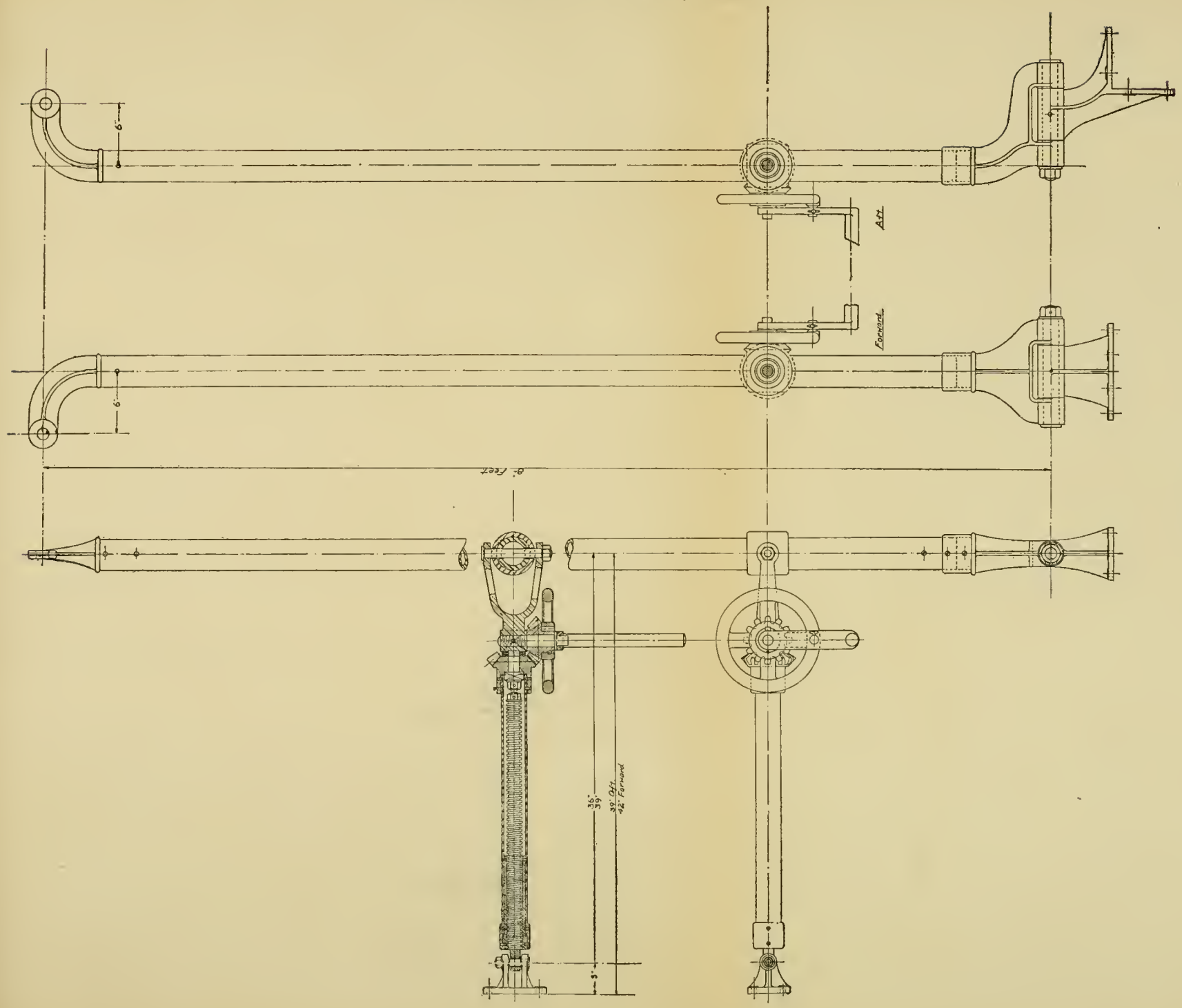
SUNVALVE AND FLASHER.

To illustrate paper on "Marine Lighting Equipment for the Panama Canal," by James Pattison, Esq.



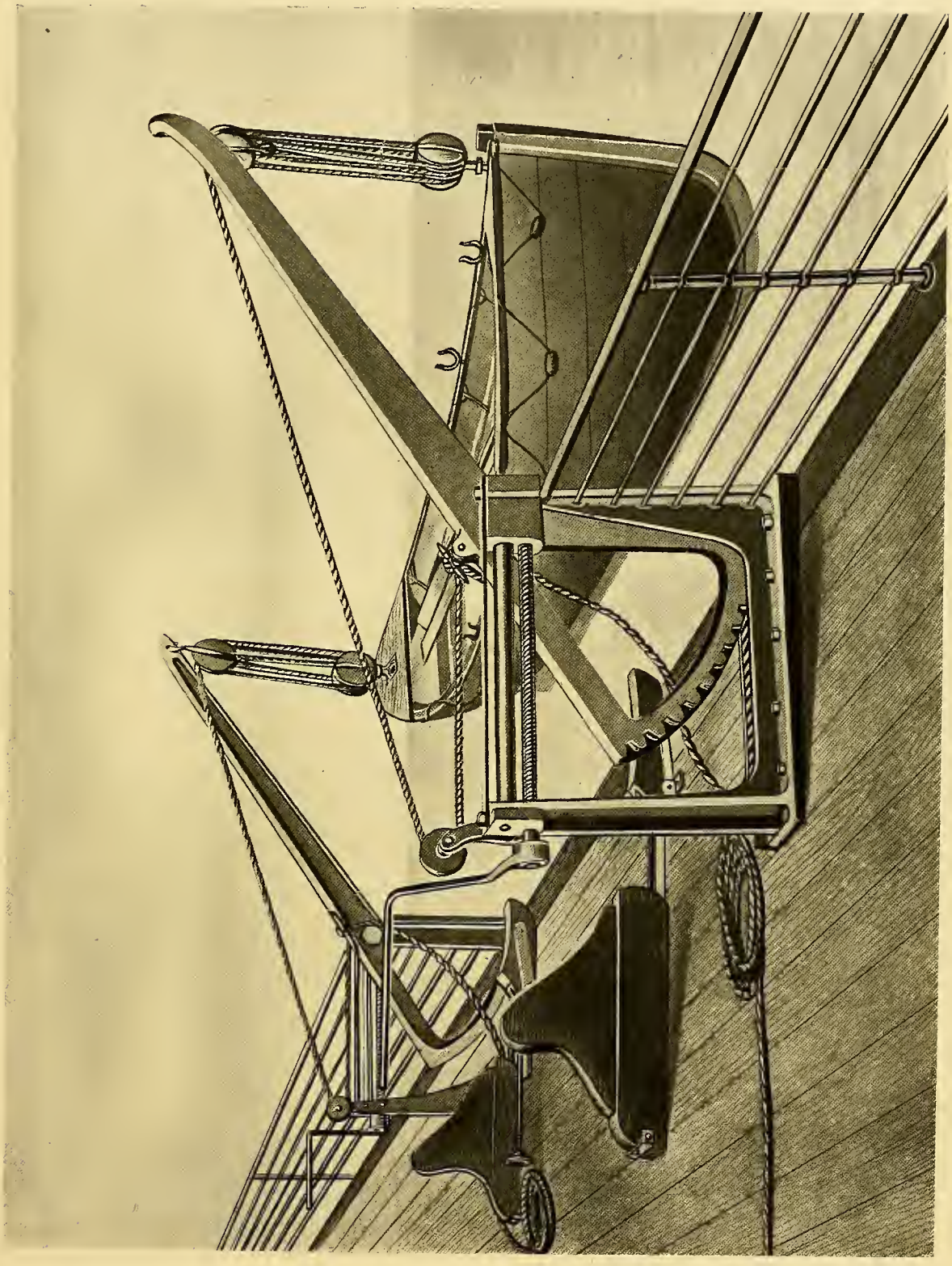
Sunvalve Economy Diagram.

To illustrate paper on "Notes on Life-Saving Appliances," by W. D. Forbes, Esq., Member of Council.



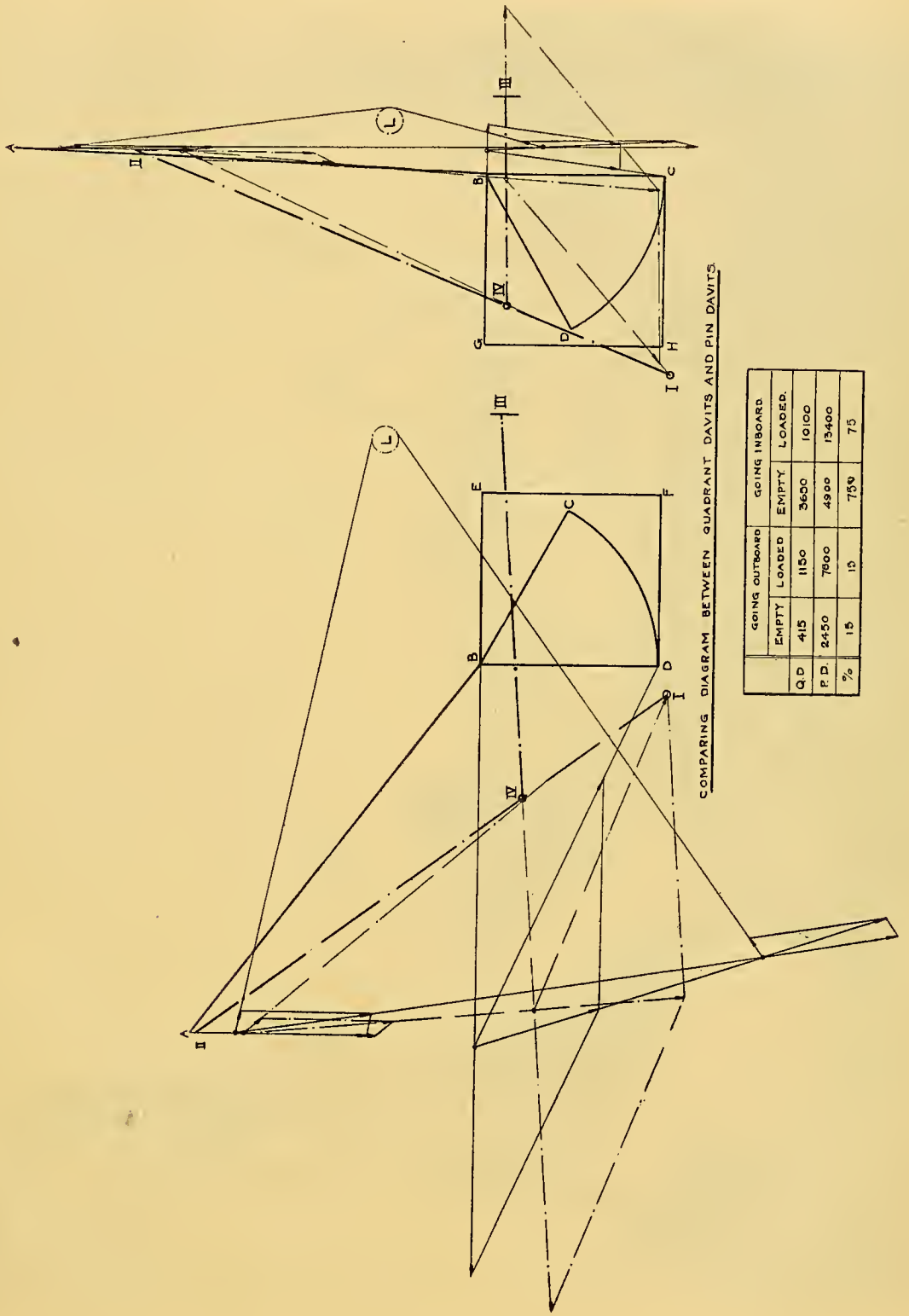
FIXED PIN DAVIT.

To illustrate paper on "Notes on Life-Saving Appliances," by W. D. Forbes, Esq., Member of Council.

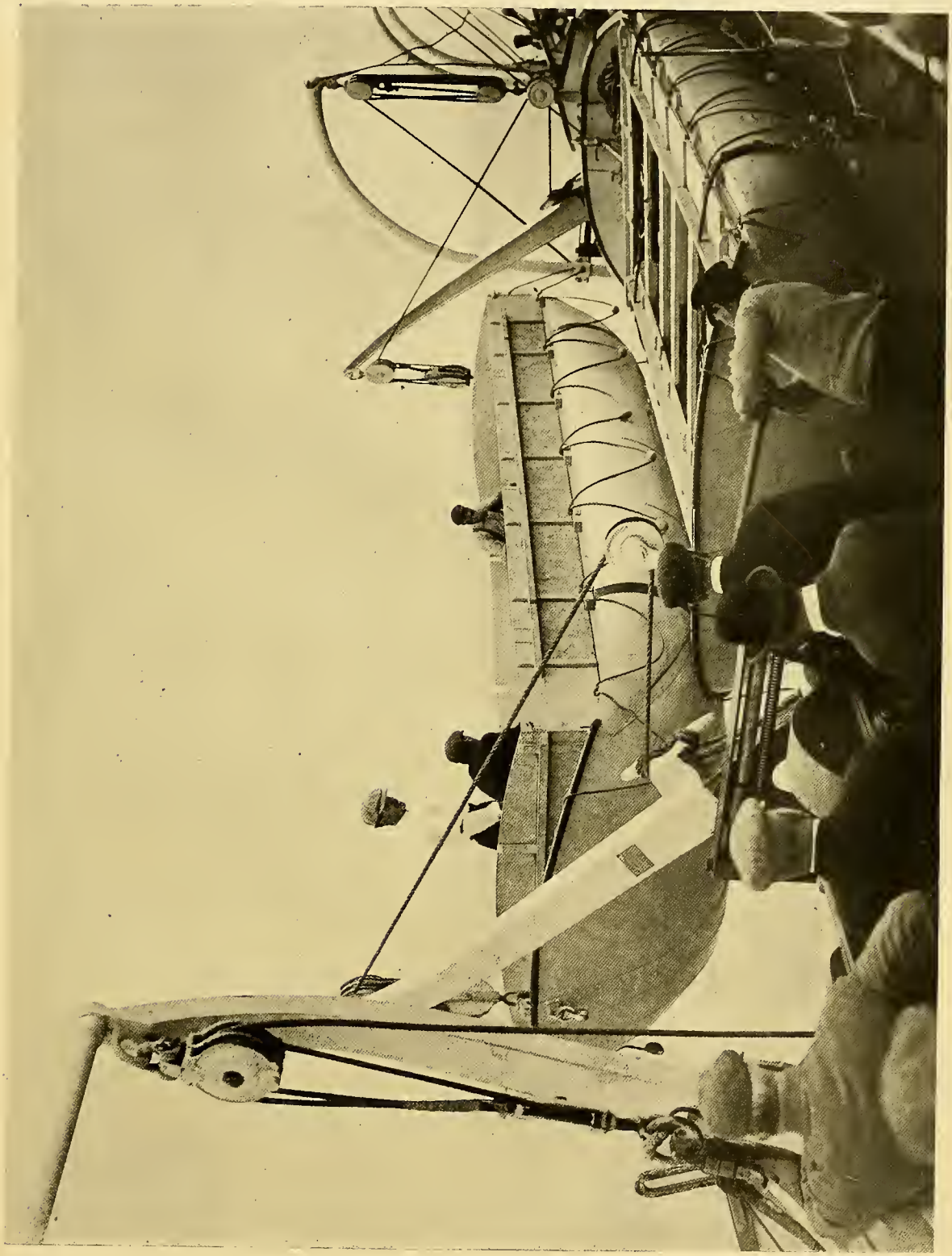


Movable Pin Davit.

To illustrate paper on "Notes on Life-Saving Appliances," by W. D. Forbes, Esq., Member of Council.

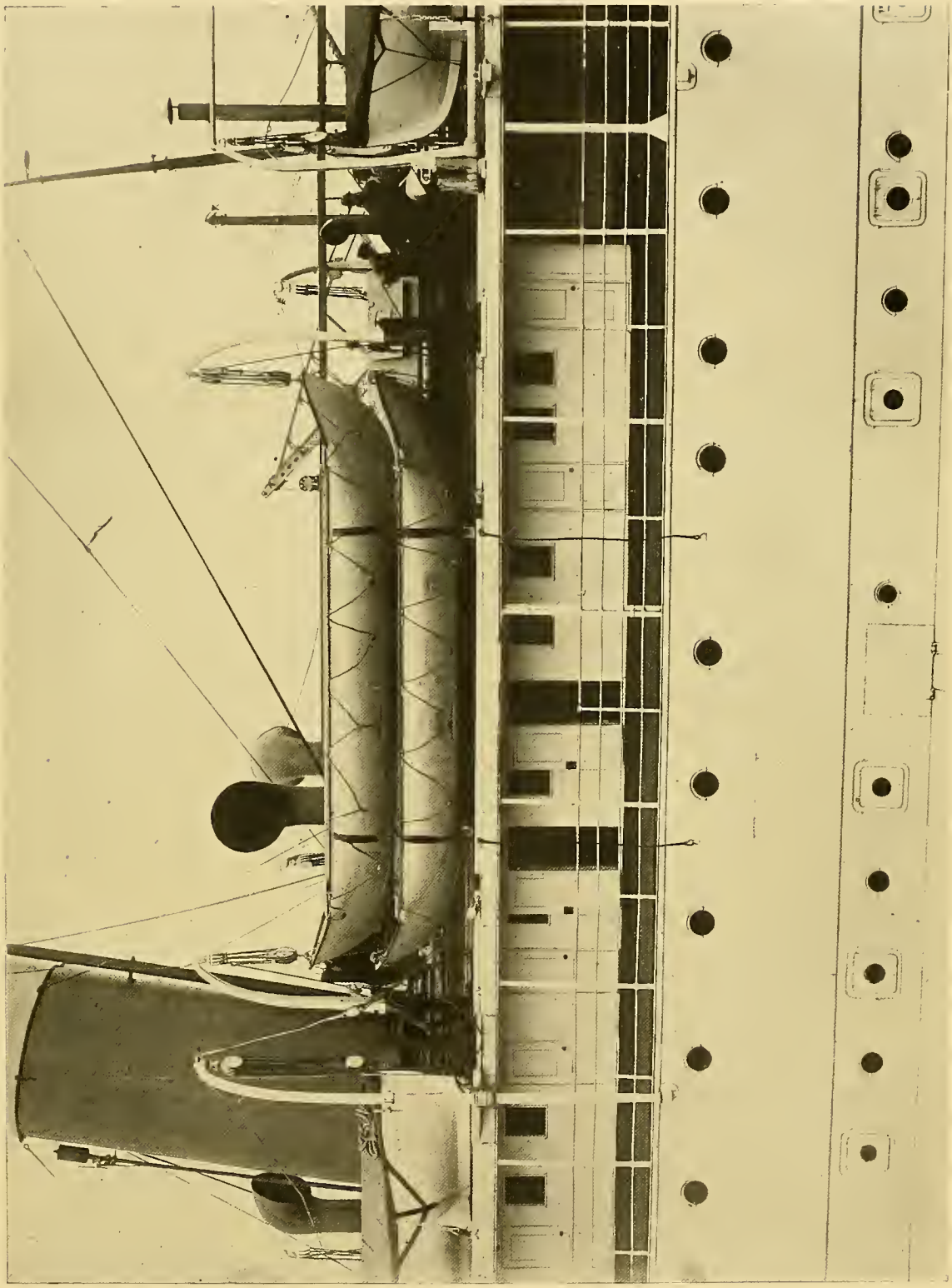


To illustrate paper on "Notes on Life-Saving Appliances," by W. D. Forbes, Esq., Member of Council.



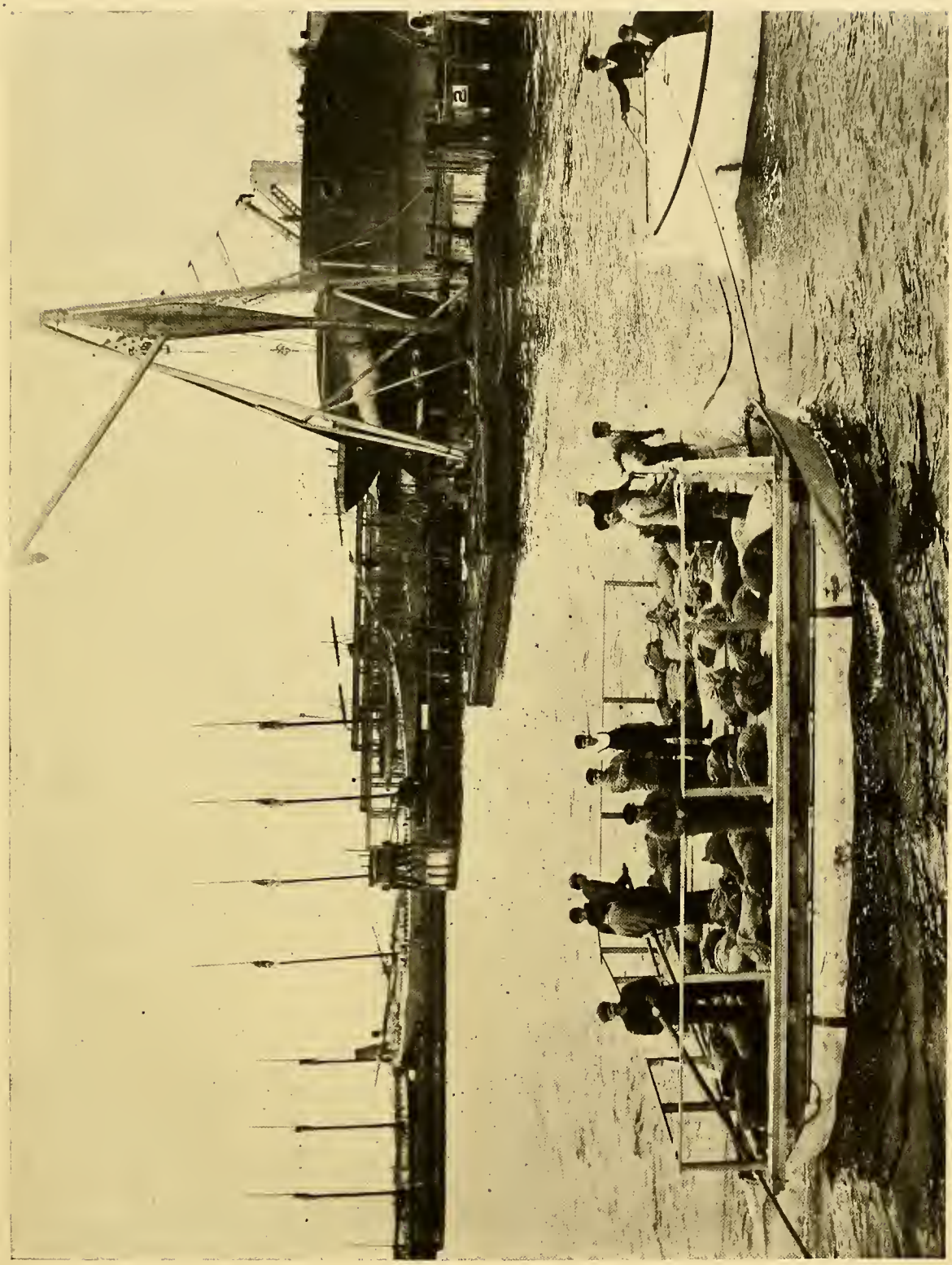
LIFEBOAT.

To illustrate paper on "Notes on Life-Saving Appliances," by W. D. Forbes, Esq., Member of Council.



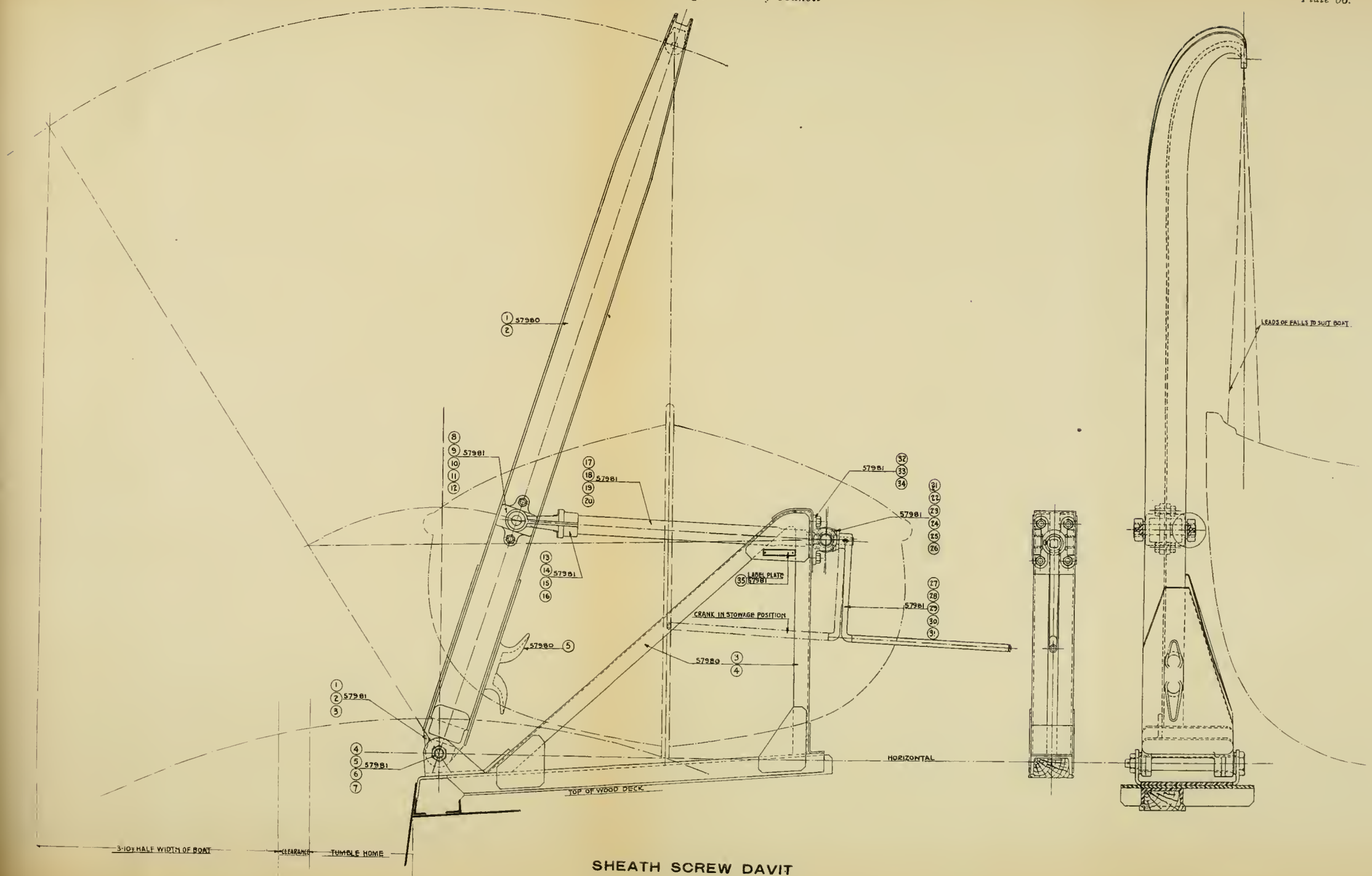
LIFEBOAT.

To illustrate paper on "Notes on Life-Saving Appliances," by W. D. Forbes, Esq., Member of Council.



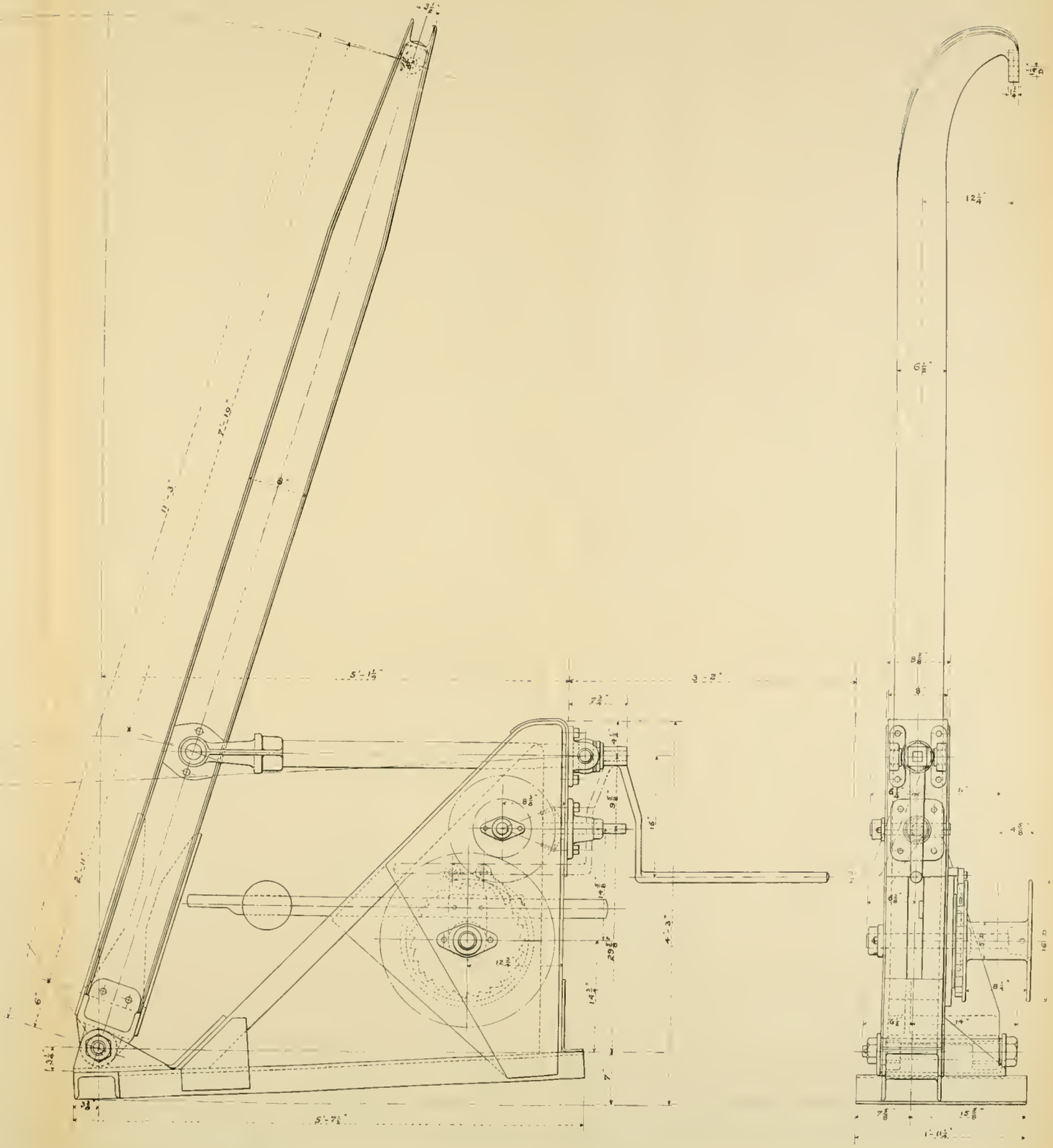
LIFEBOATS AS PONTOONS.

To illustrate discussion on "Notes on Life-Saving Appliances," by W. D. Forbes, Esq., Member of Council



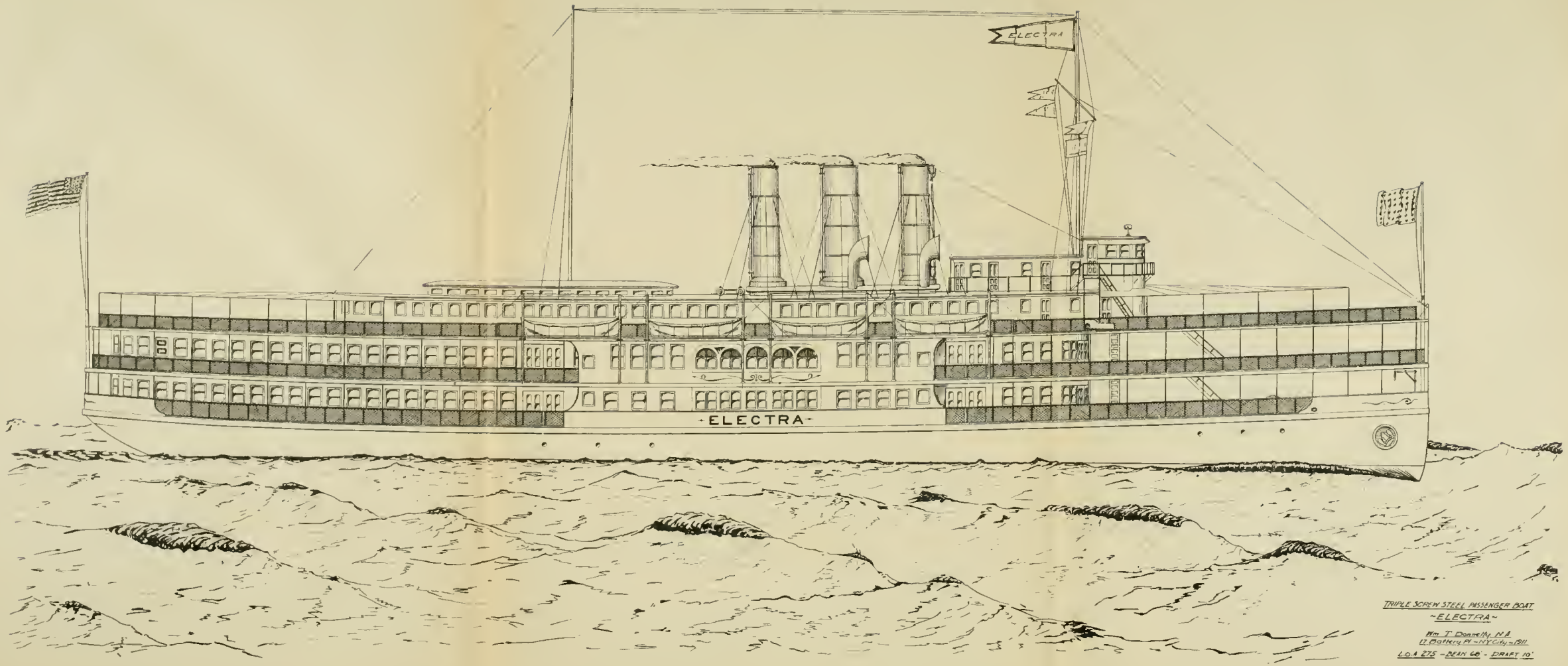
SHEATH SCREW DAVIT

To illustrate discussion on "Notes on Life-Saving Appliances," by W. D. Forbes, Esq., Member of Council

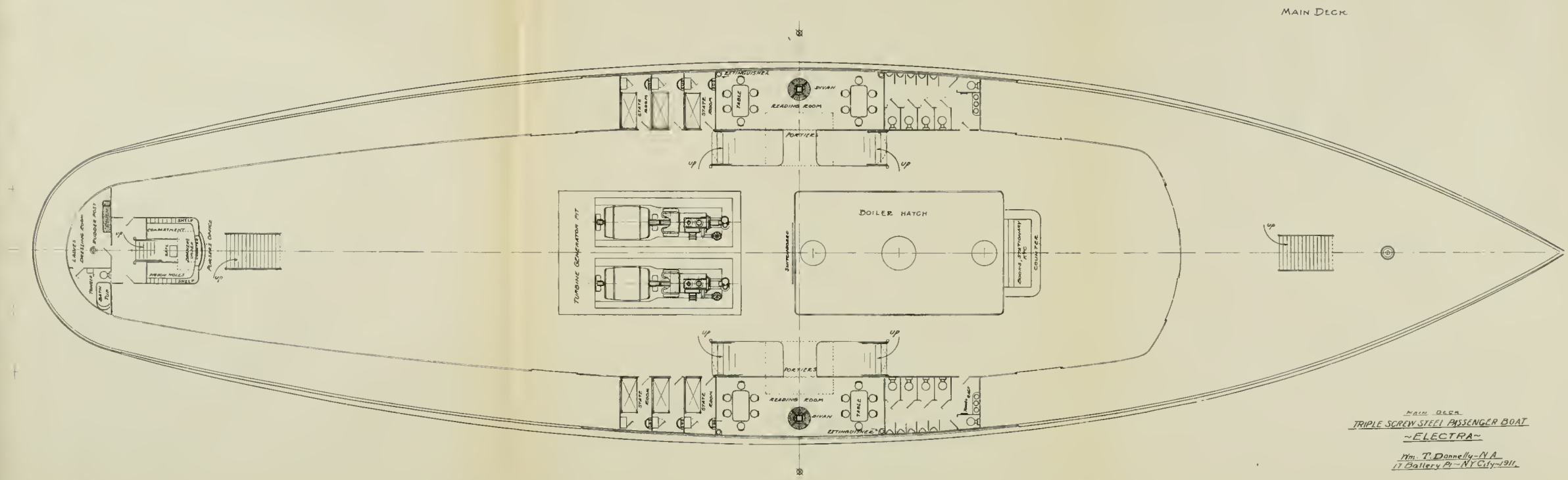


NORTON SHEATH SCREW DAVIT
WITH
BOAT WINCH

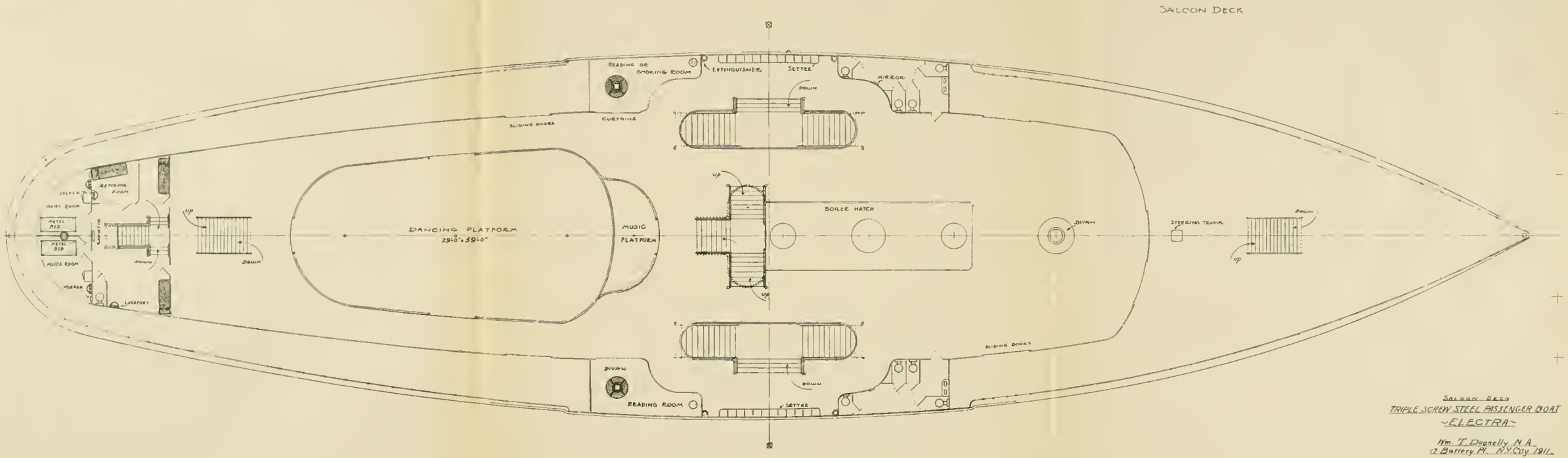
To illustrate paper on "An Electrically Propelled Fireproof Passenger Steamer," by W. T. Donnelly, Esq., and G. A. Orrok, Esq., Members.



To illustrate paper on "An Electrically Propelled Fireproof Possenger Steamer," by W. T. Donnelly, Esq., and G. A. Orrok, Esq., Members.



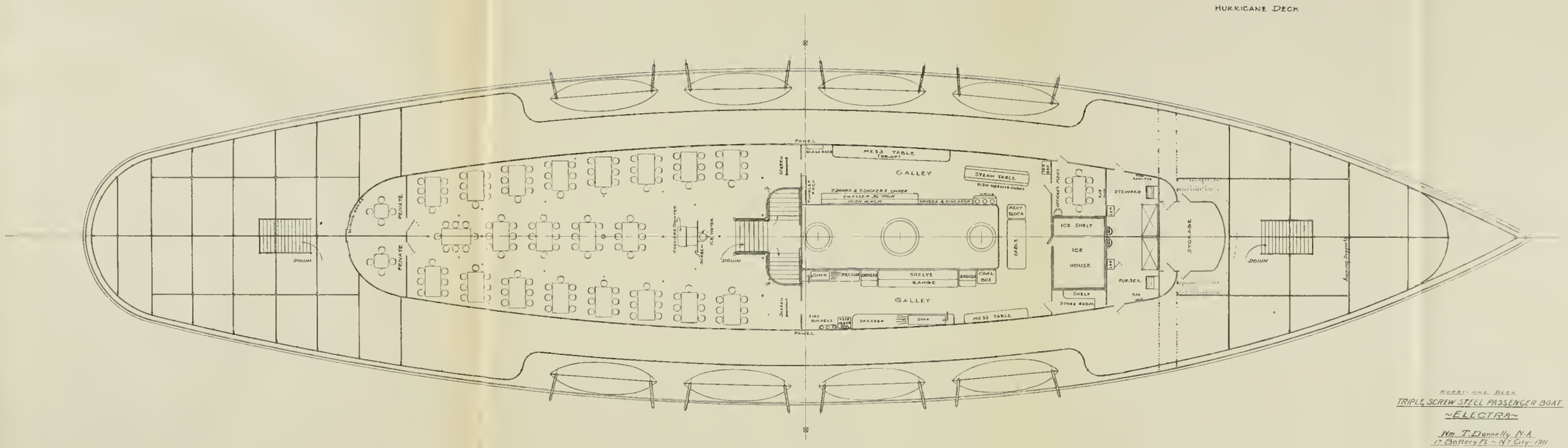
To illustrate paper on "An Electrically Propelled Fireproof Passenger Steamer," by W. T. Donnelly, Esq., and G. A. Orrok, Esq., Members.



SALOON DECK
TRIPLE SCREW STEEL PASSENGER BOAT
~ELECTRA~

Wm. T. Donnelly N.A.
17 Battery Pl. N.Y. City 1911.

To illustrate paper on "An Electrically Propelled Fireproof Passenger Steamer," by W. T. Donnelly, Esq., and G. A. Orrok, Esq., Members.



HURRICANE DECK

TRIPLE SCREW STEEL PASSENGER BOAT

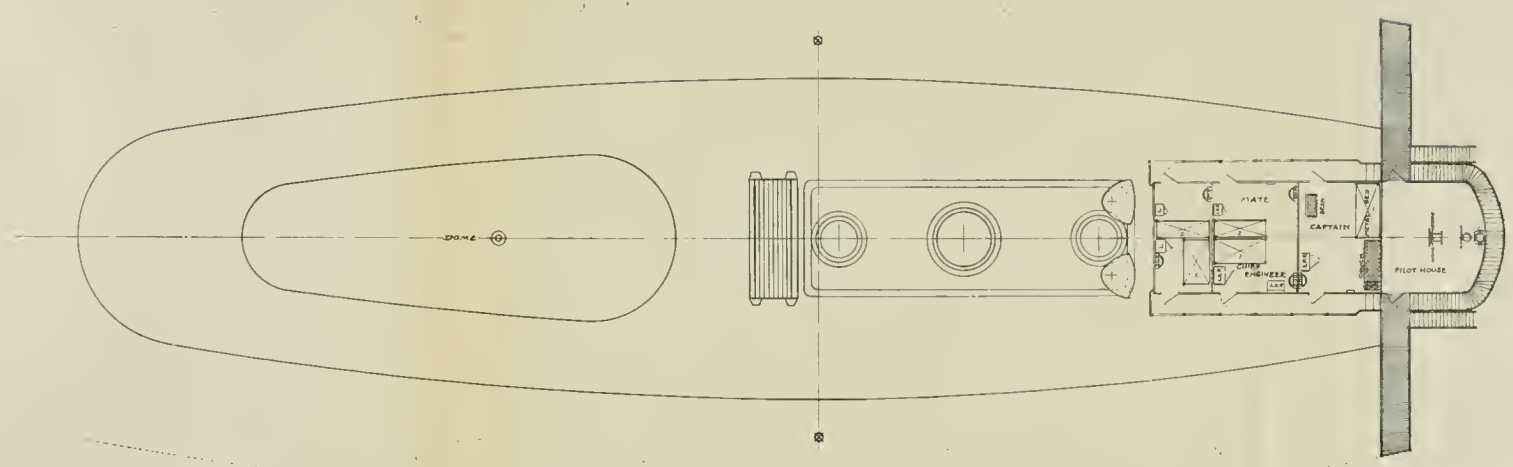
~ELECTRA~

Wm. T. Donnelly N.A.

17 Battery Pl. – N.Y. City – 1911

To illustrate paper on "An Electrically Propelled Fireproof Passenger Steamer," by W. T. Donnelly, Esq., and G. A. Orrok, Esq., Members.

DOME DECK

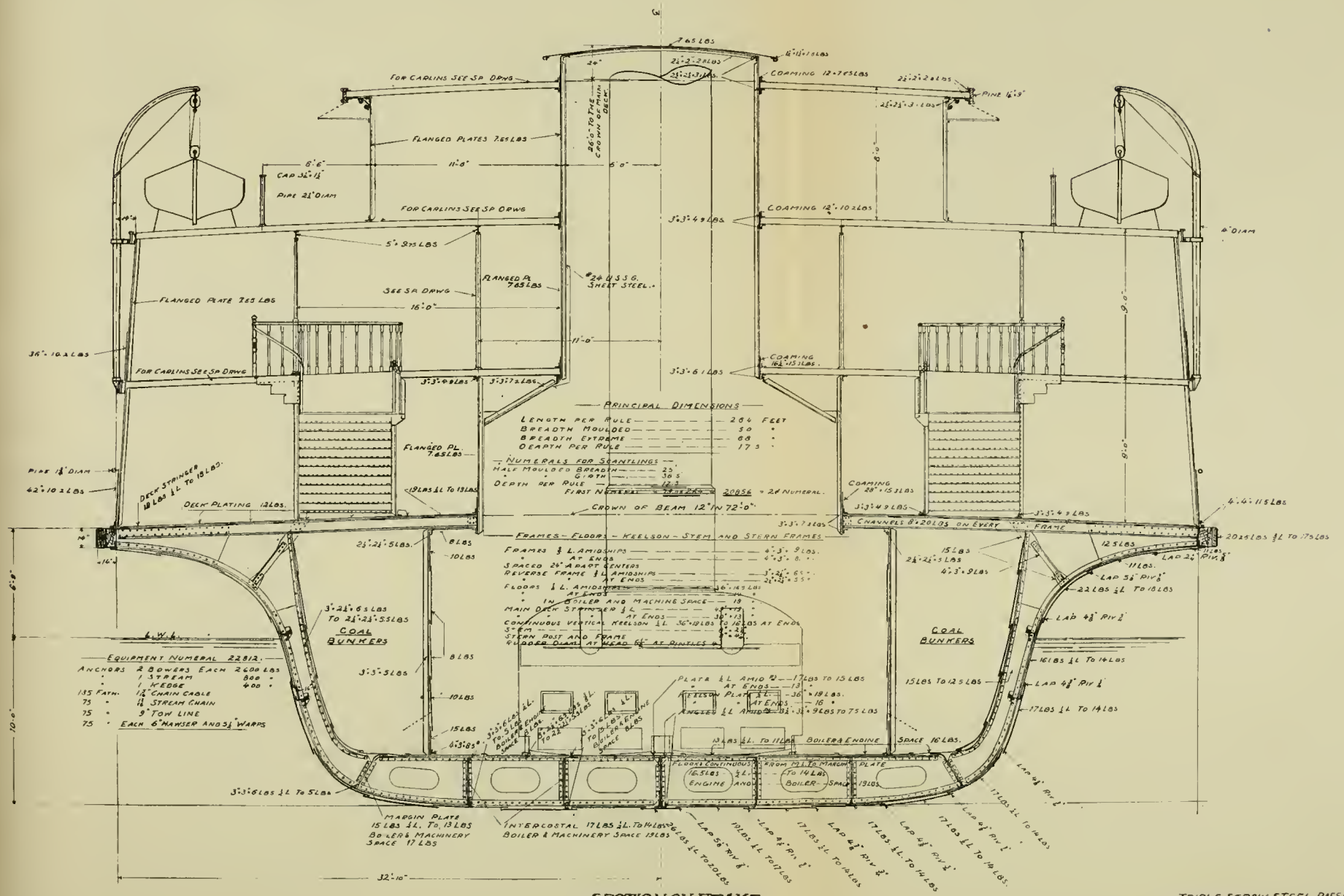


DOME DECK
TRIPLE SCREW STEEL PASSENGER BOAT
~ELECTRA~

Wm. T. Donnelly-N.A.
17 Battery Pl.-N.Y. City 1911.

To illustrate paper on "An Electrically Propelled Fireproof Passenger Steamer," by W. T. Donnelly, Esq., and G. A. Orrok, Esq., Members.

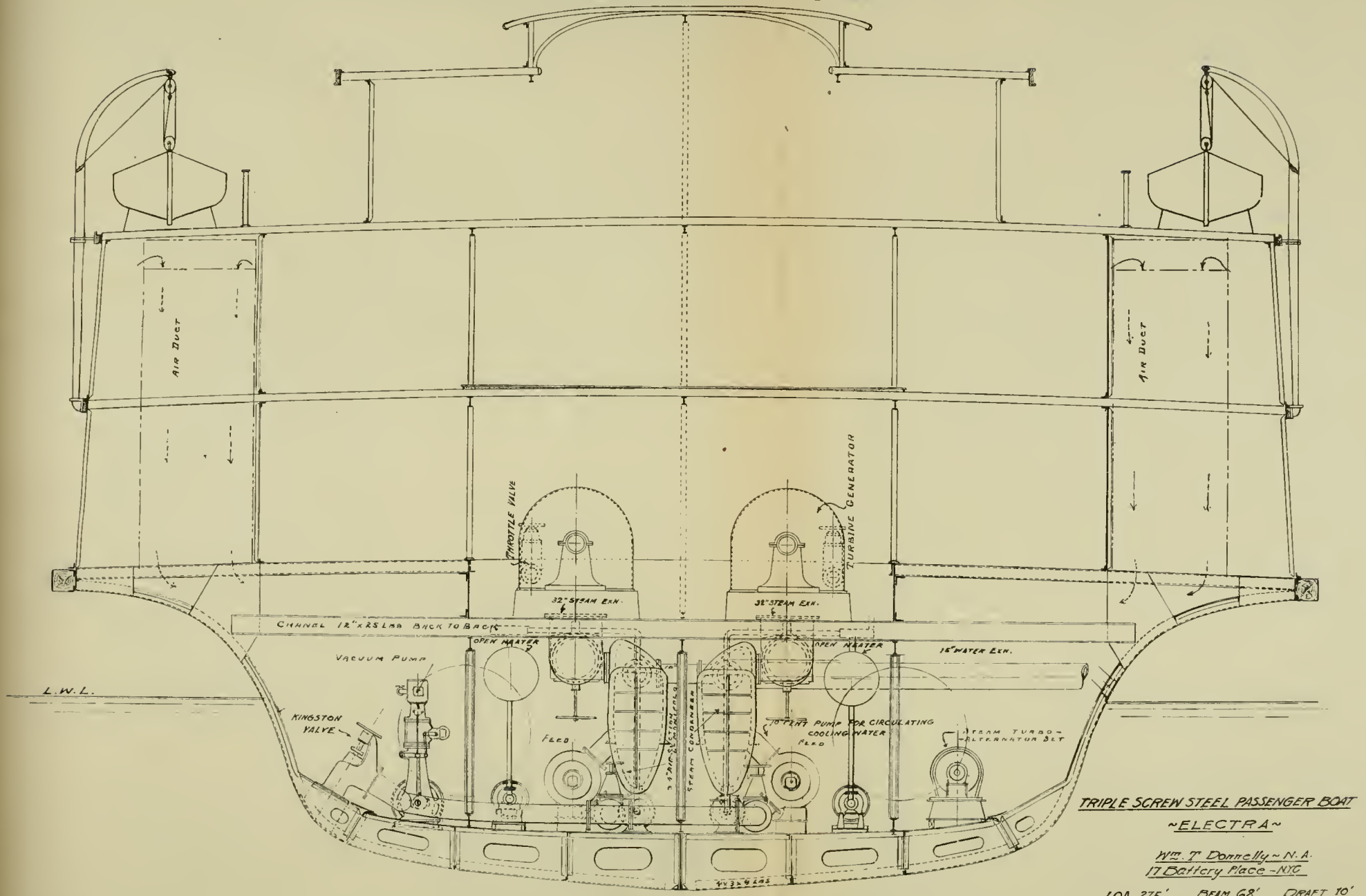
MID SHIP SECTION
OF A
TRIPLE SCREW PASSENGER BOAT.
FOR
SOUND OR BAY SERVICE.
SCALE: ¼" = ONE FT



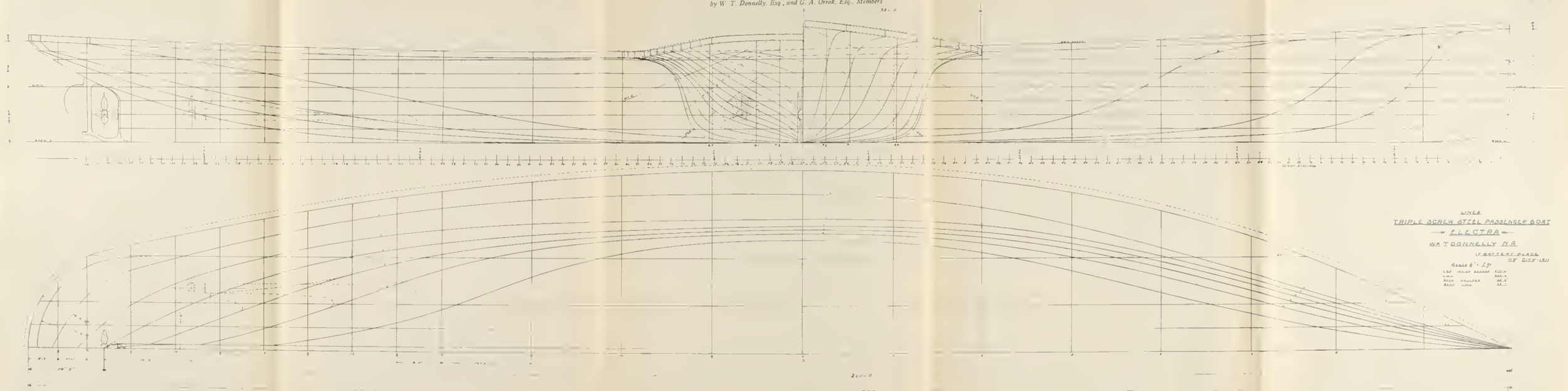
~ SECTION ON FRAME ~
NO. 66.
~ XX ~

TRIPLE SCREW STEEL PASSENGER BOAT
~ ELECTRA ~

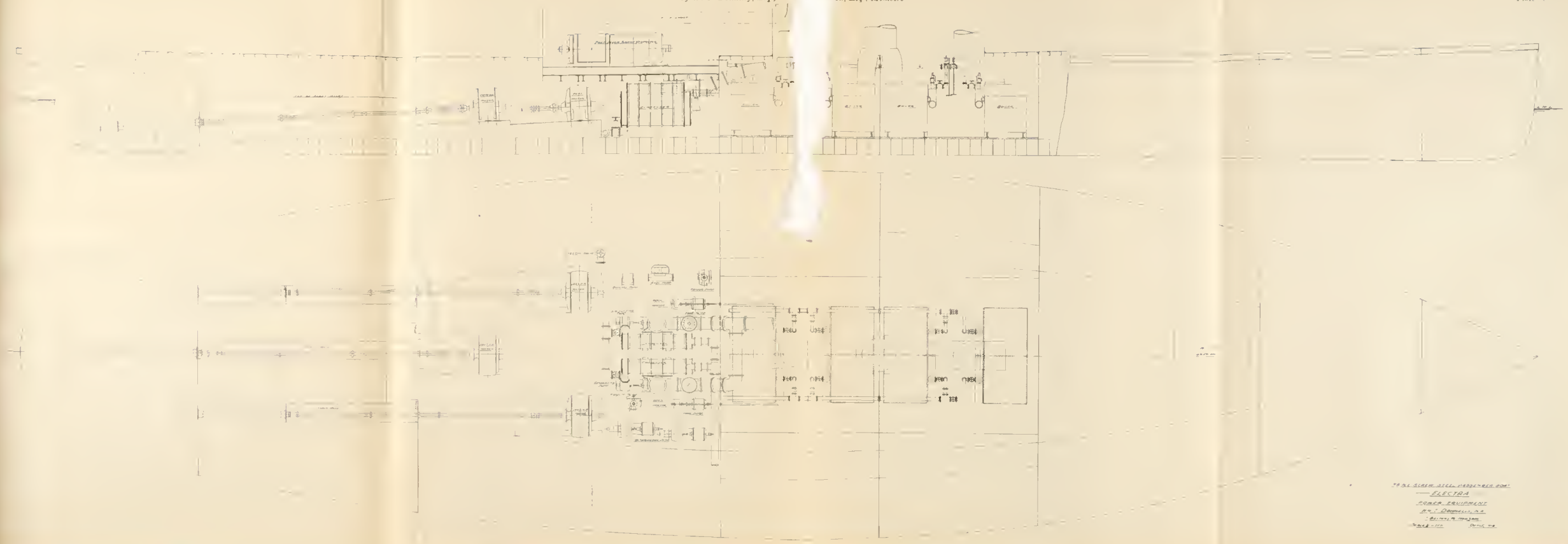
To illustrate paper on "An Electrically Propelled Fireproof Passenger Steamer," by W. T. Donnelly, Esq., and G. A. Orrok, Esq., Members.



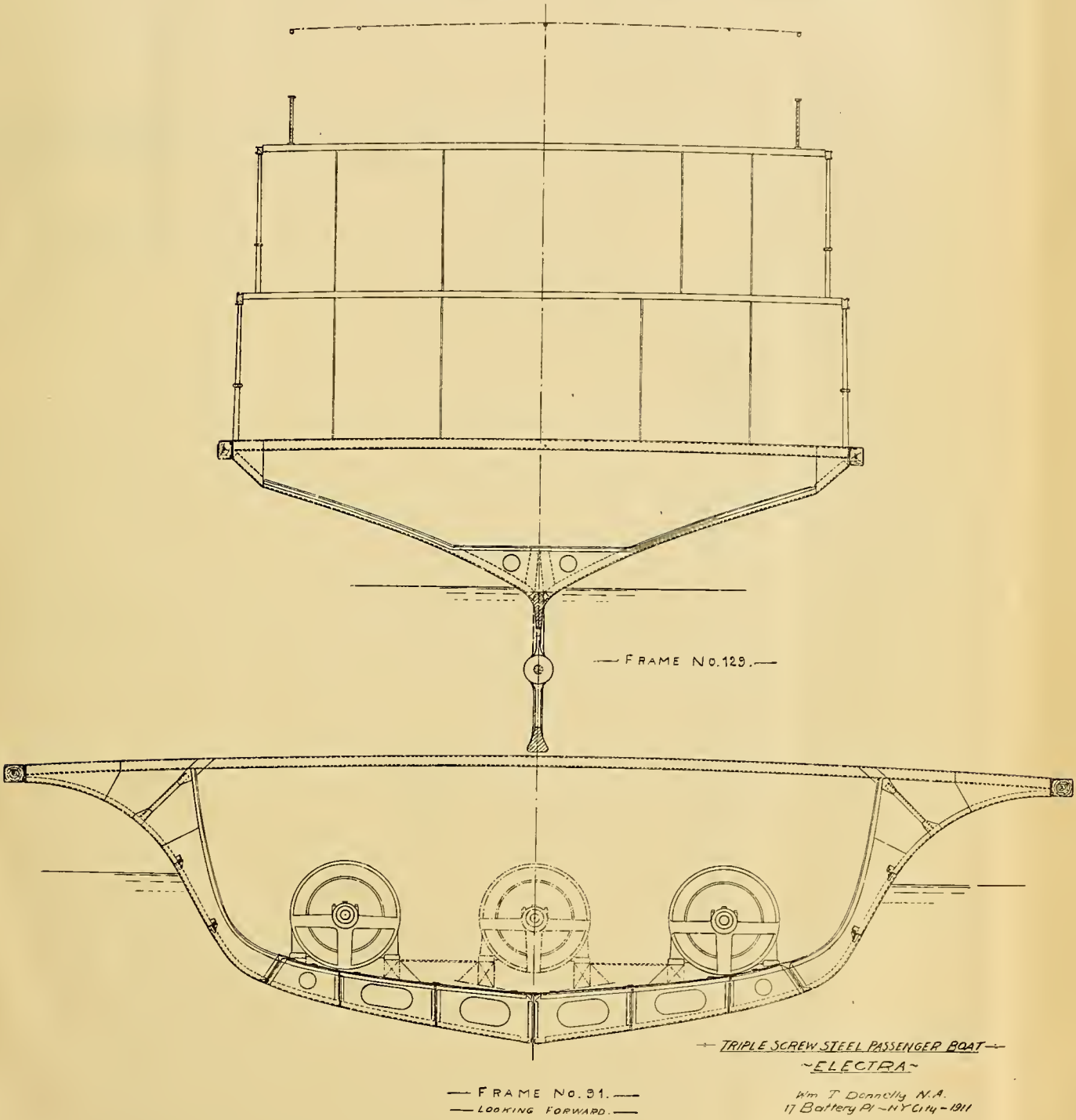
To illustrate paper on "An Electrically Propelled Fireproof Passenger Steamer," by W. T. Donnelly, Esq., and G. A. Orrok, Esq., Members



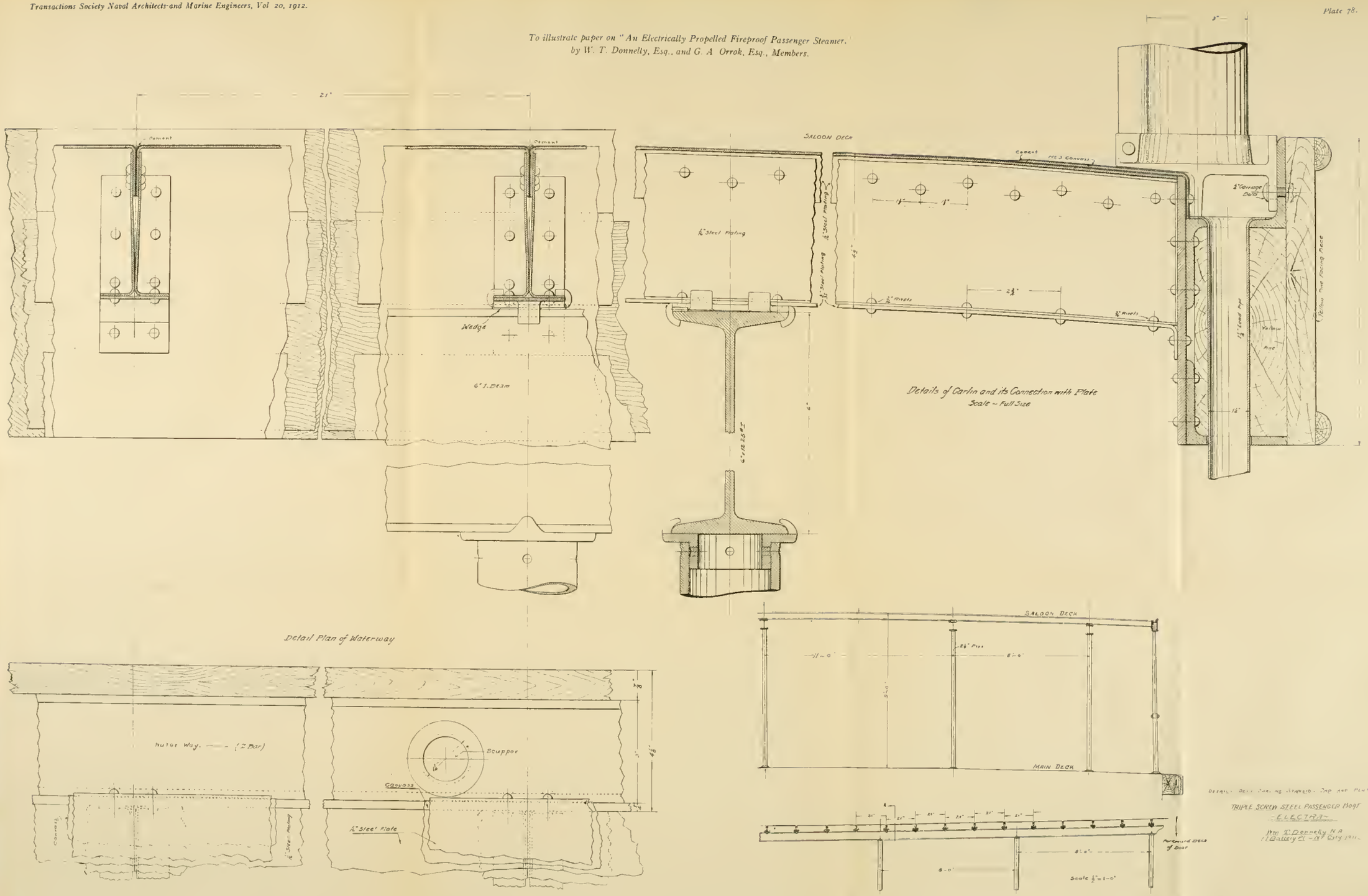
To illustrate paper on "An Electrically P[illegible] Fireproof Passenger Steamer,"
by W. T. Donnelly, Esq., and [illegible]rok, Esq., Members



To illustrate paper on "An Electrically Propelled Fireproof Passenger Steamer," by W. T. Donnelly, Esq., and G. A. Orrok, Esq., Members.



To illustrate paper on "An Electrically Propelled Fireproof Passenger Steamer," by W. T. Donnelly, Esq., and G. A. Orrok, Esq., Members.



To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

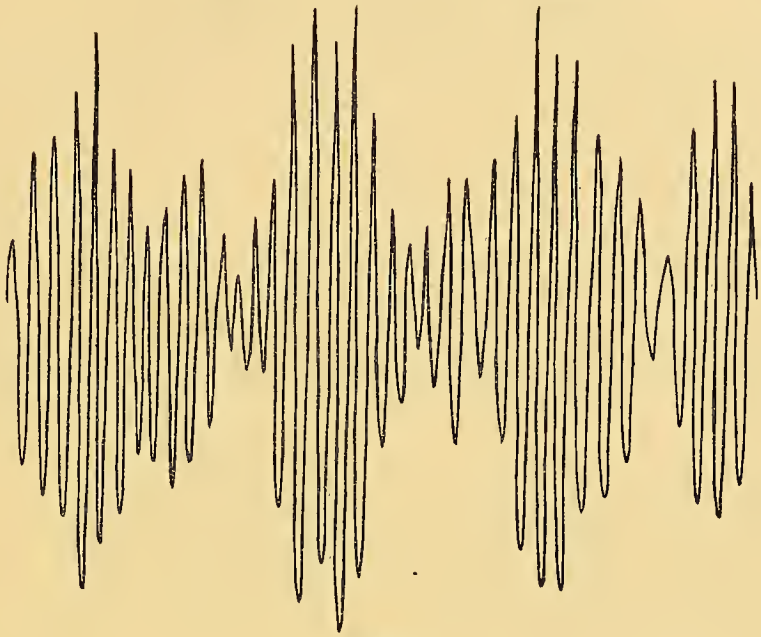


FIGURE 1

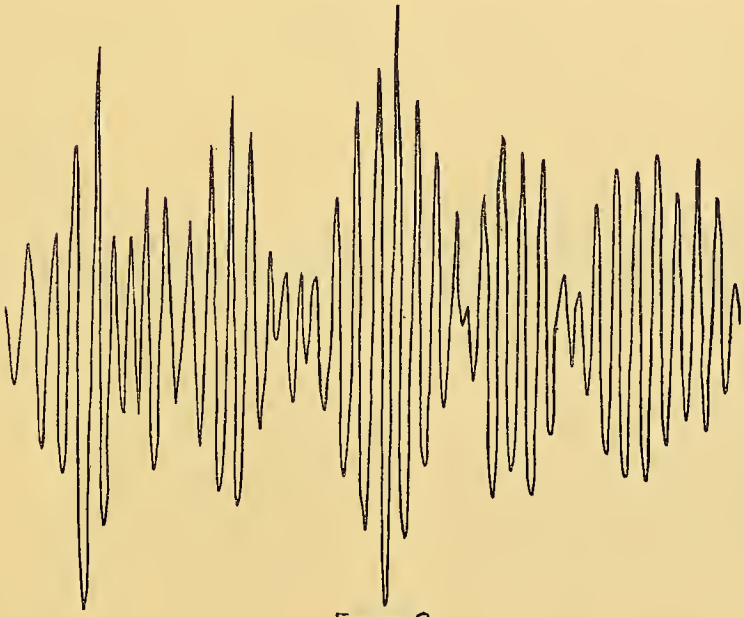


FIGURE 2

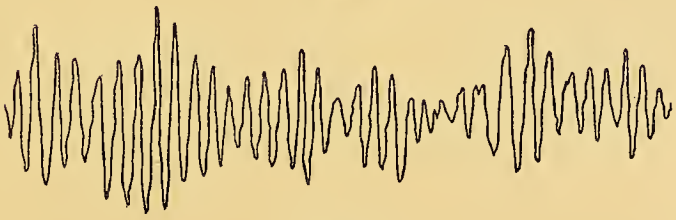
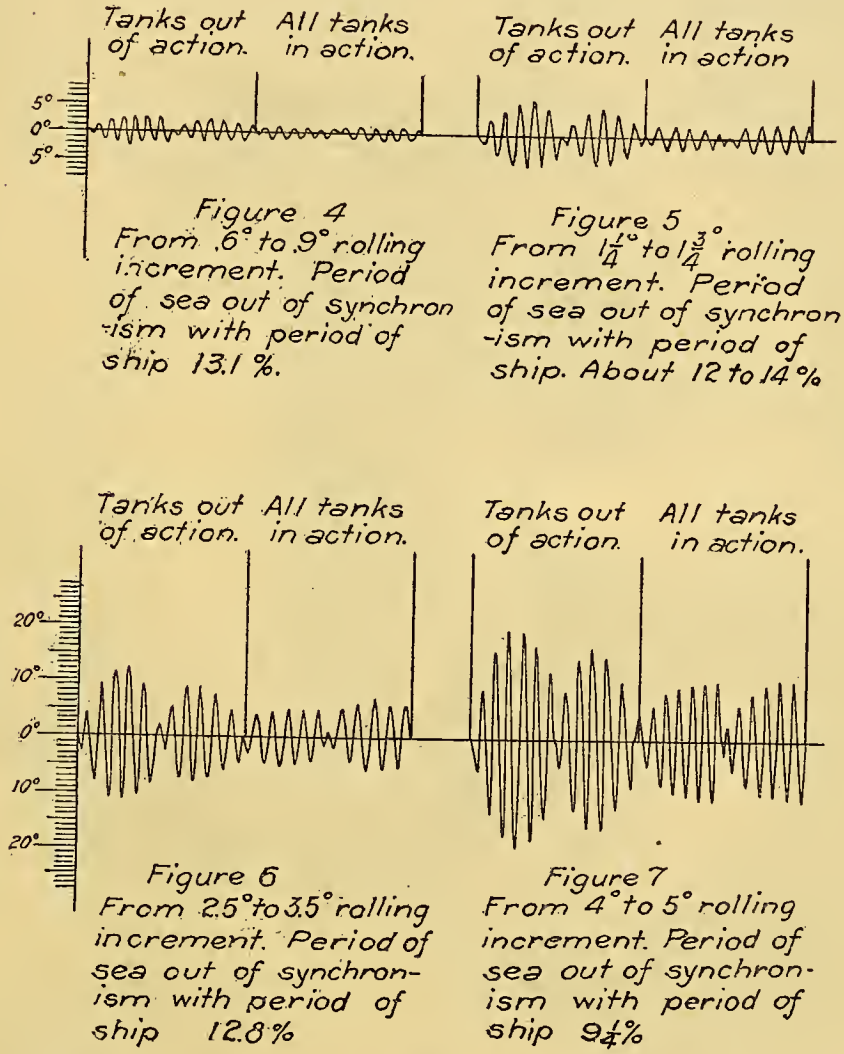


FIGURE 3

FIGS. 1, 2 AND 3.—CURVES OF UNDAMPED ROLLING OF SHIP IN DIFFERENT SEAS.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A Sperry, Esq., Member.



FIGS. 4, 5, 6 AND 7.—CURVES SHOWING ACTION OF DAMPING TANKS.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

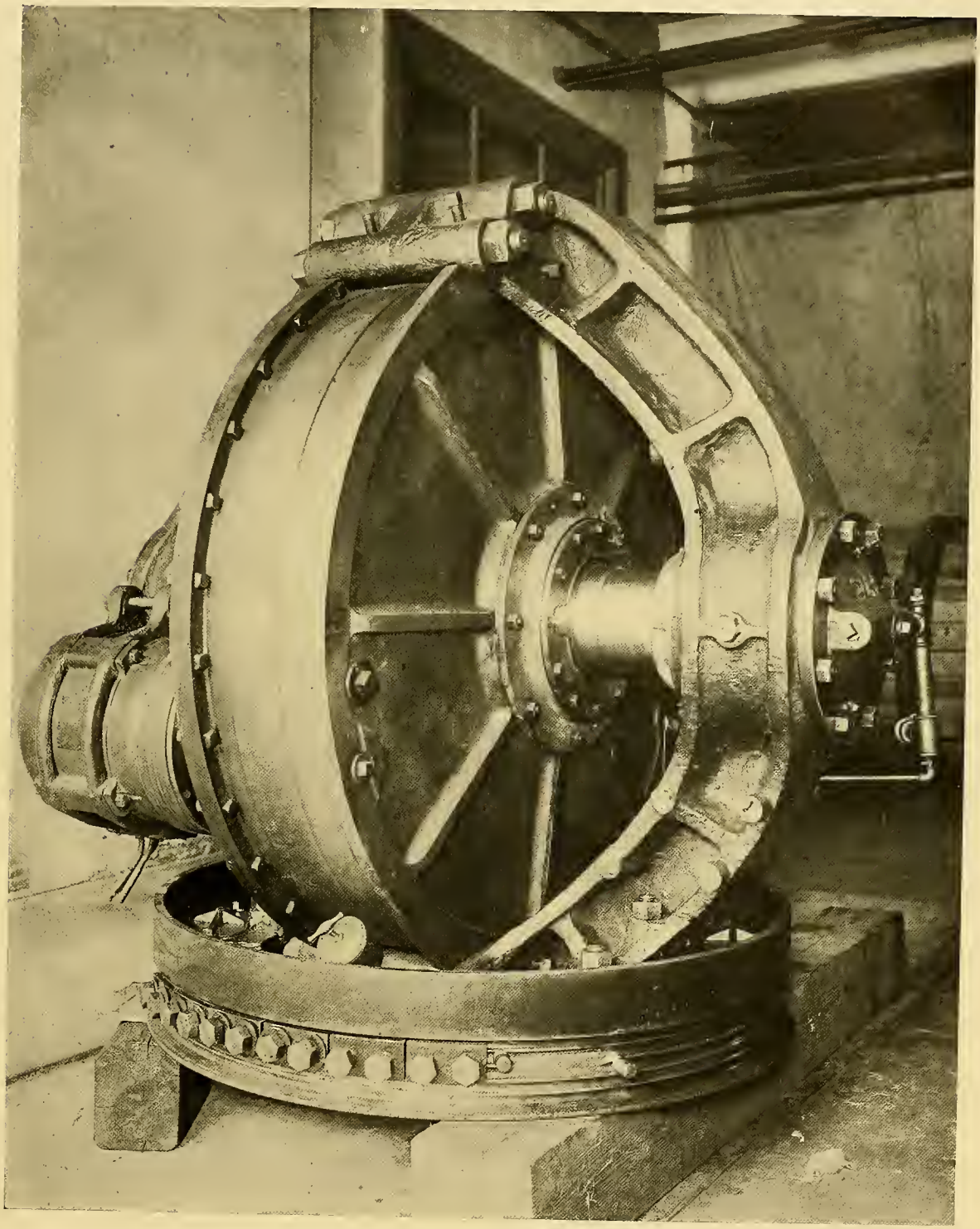


FIG. 8.—ONE OF THE ACTIVE GYROS OF THE WORDEN.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

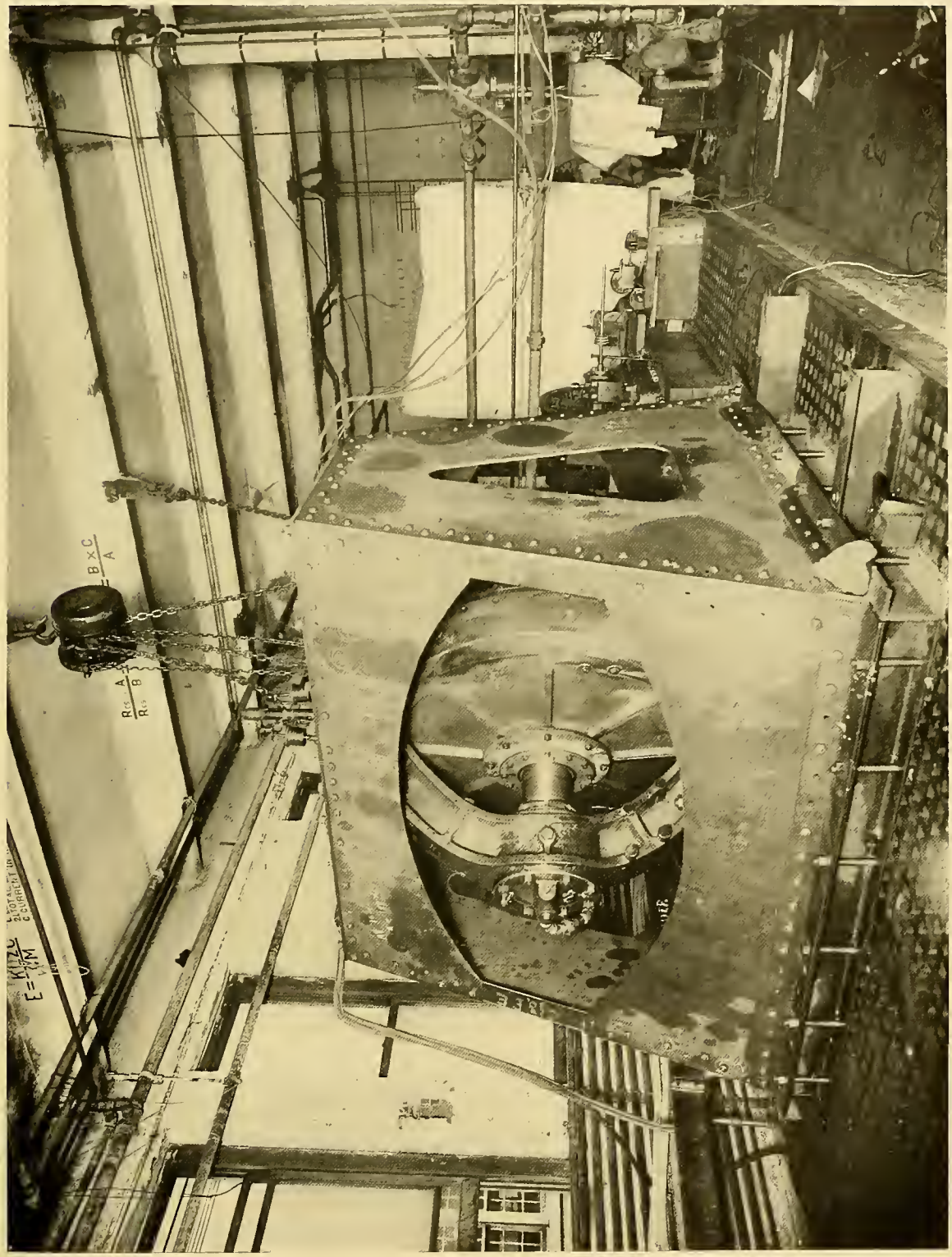


Fig. 9.—One of the Active Gyros in the Tower During Shore Trials.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

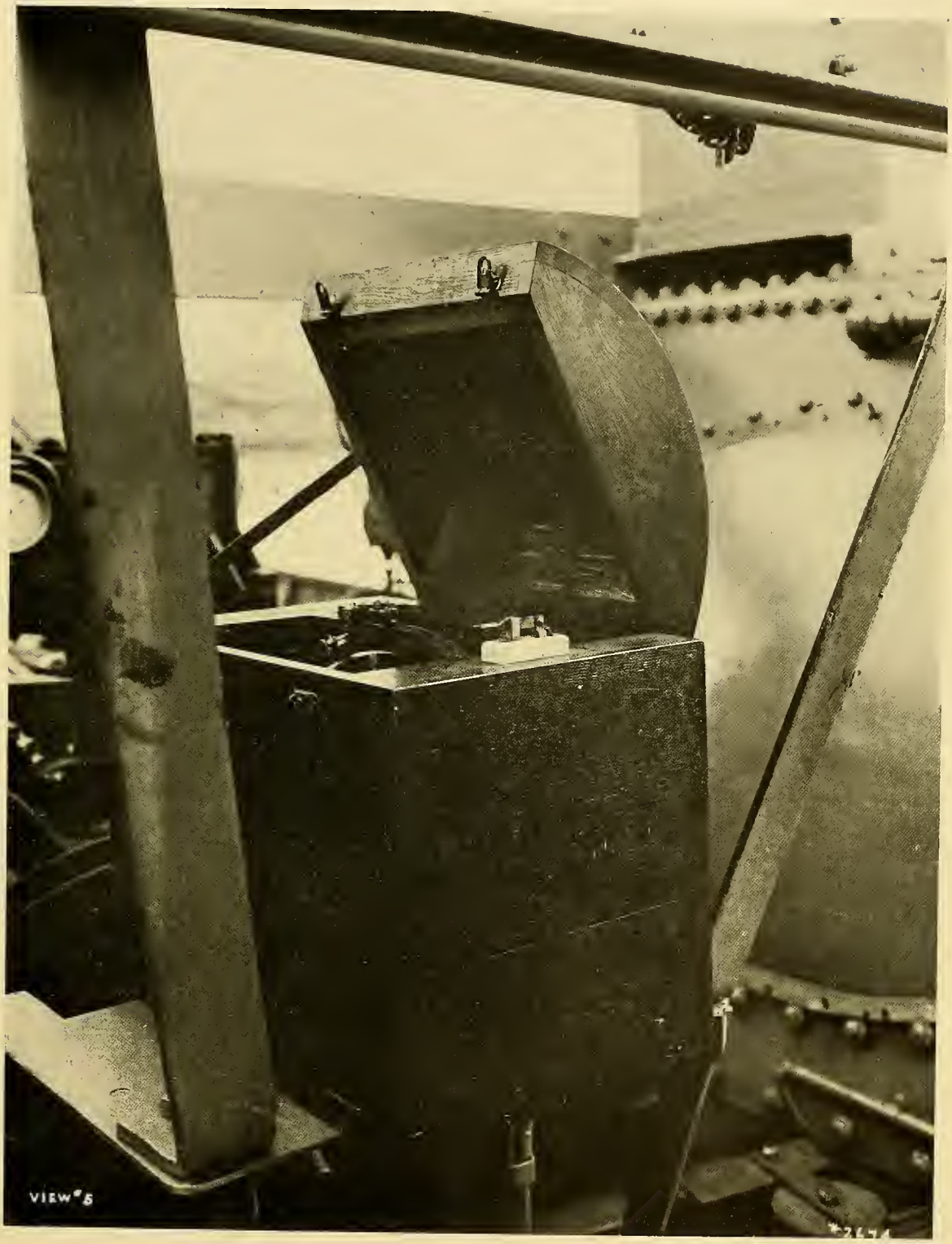


Fig. 11.—Automatic Controlling Apparatus.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

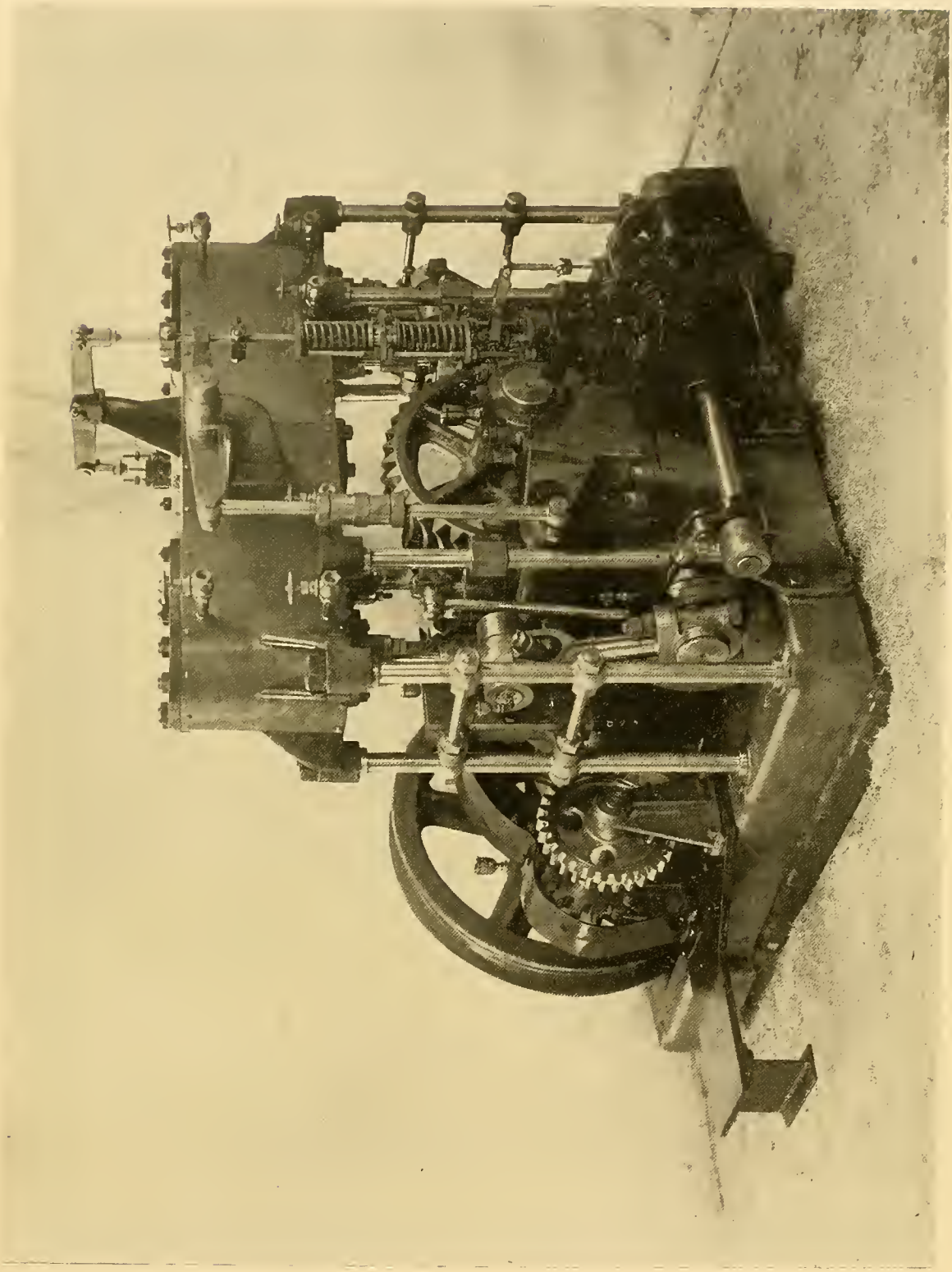


FIG. 12A.—PHOTOGRAPH OF THE PRECESSION ENGINE BEFORE INSTALLING.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

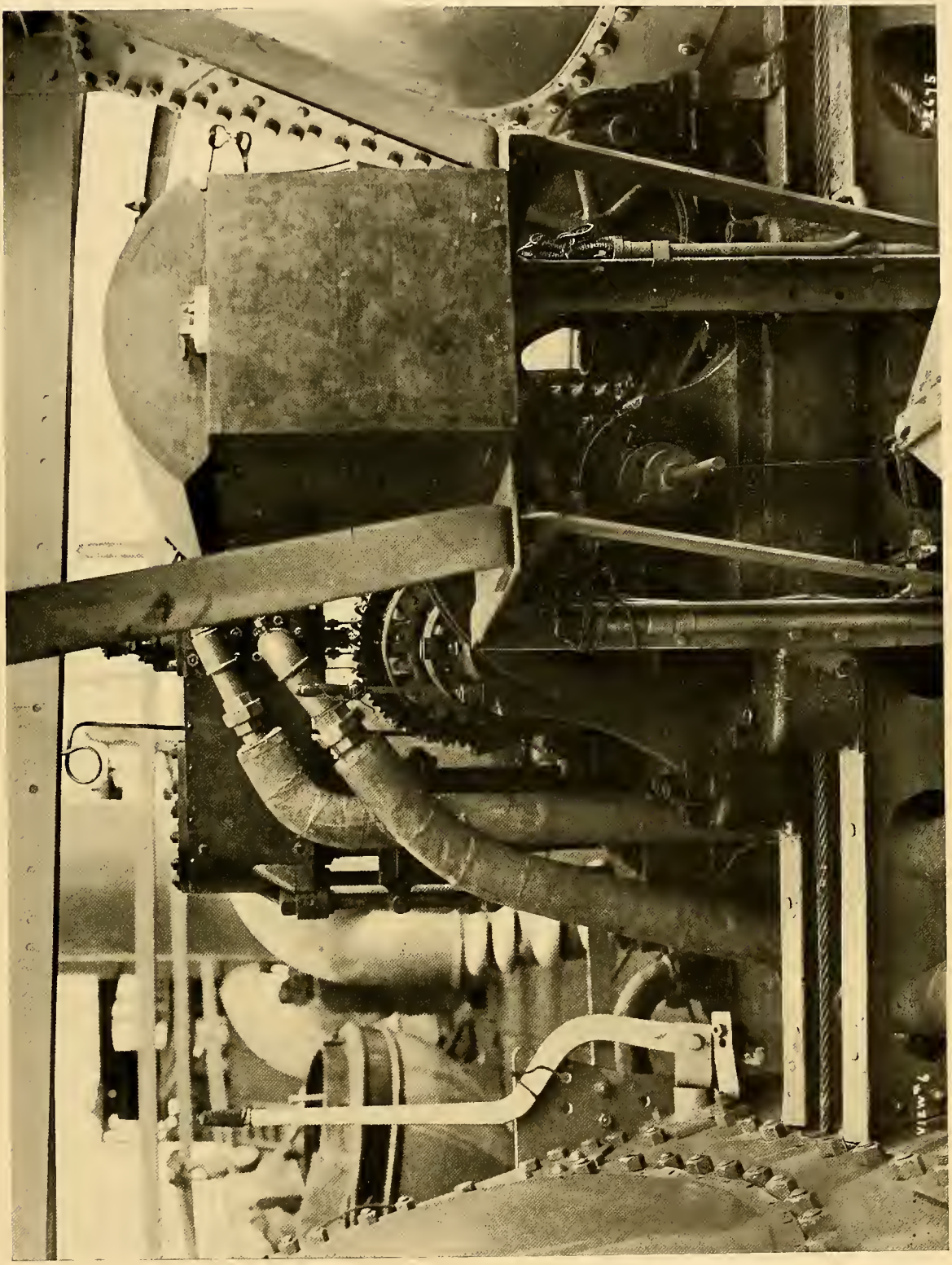


FIG. 12B.—PHOTOGRAPH OF THE PRECESSION ENGINE AFTER INSTALLING.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

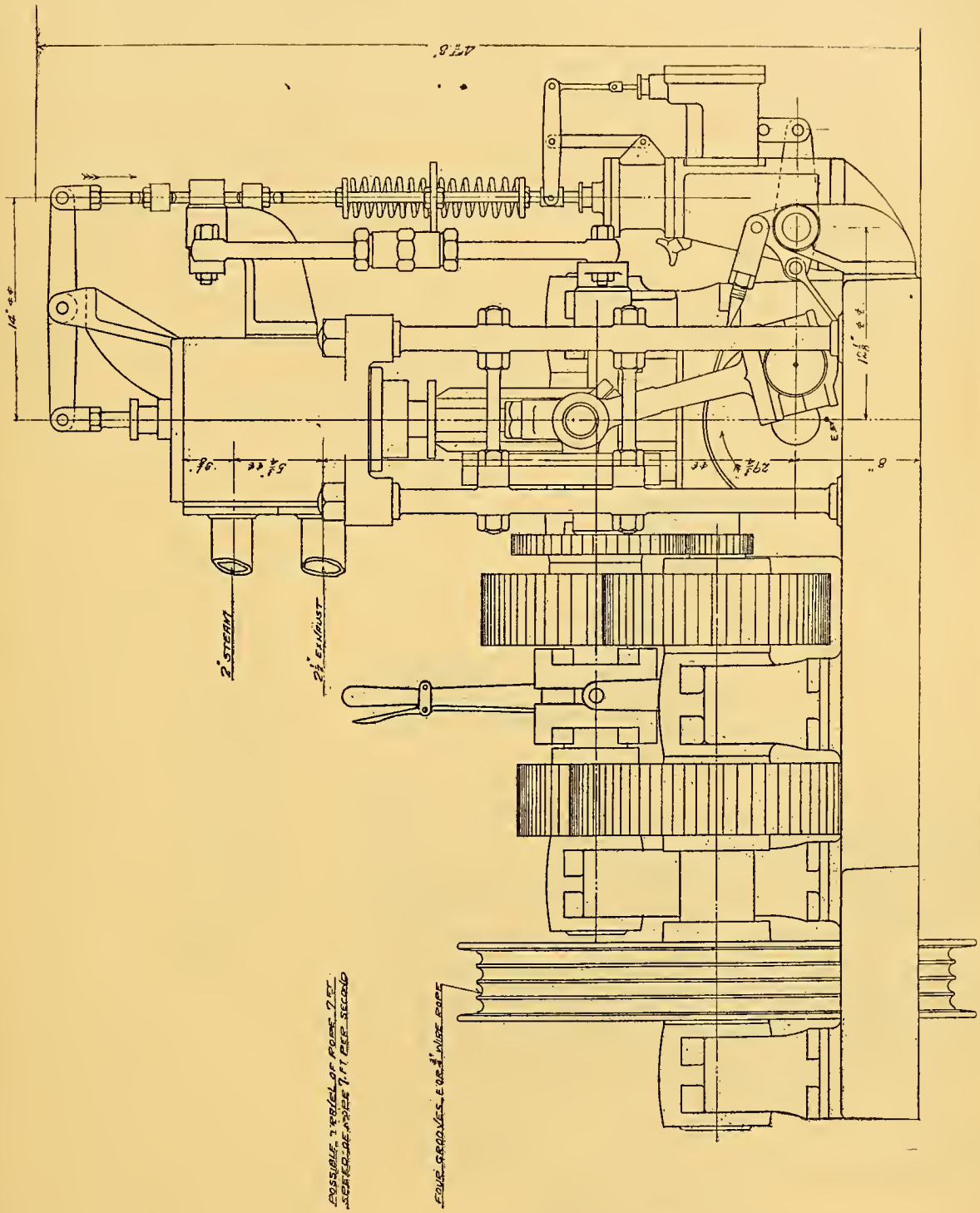


FIG. 13.—DRAWING OF THE ATHWARTSHIP ELEVATION OF PRECESSION ENGINE.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

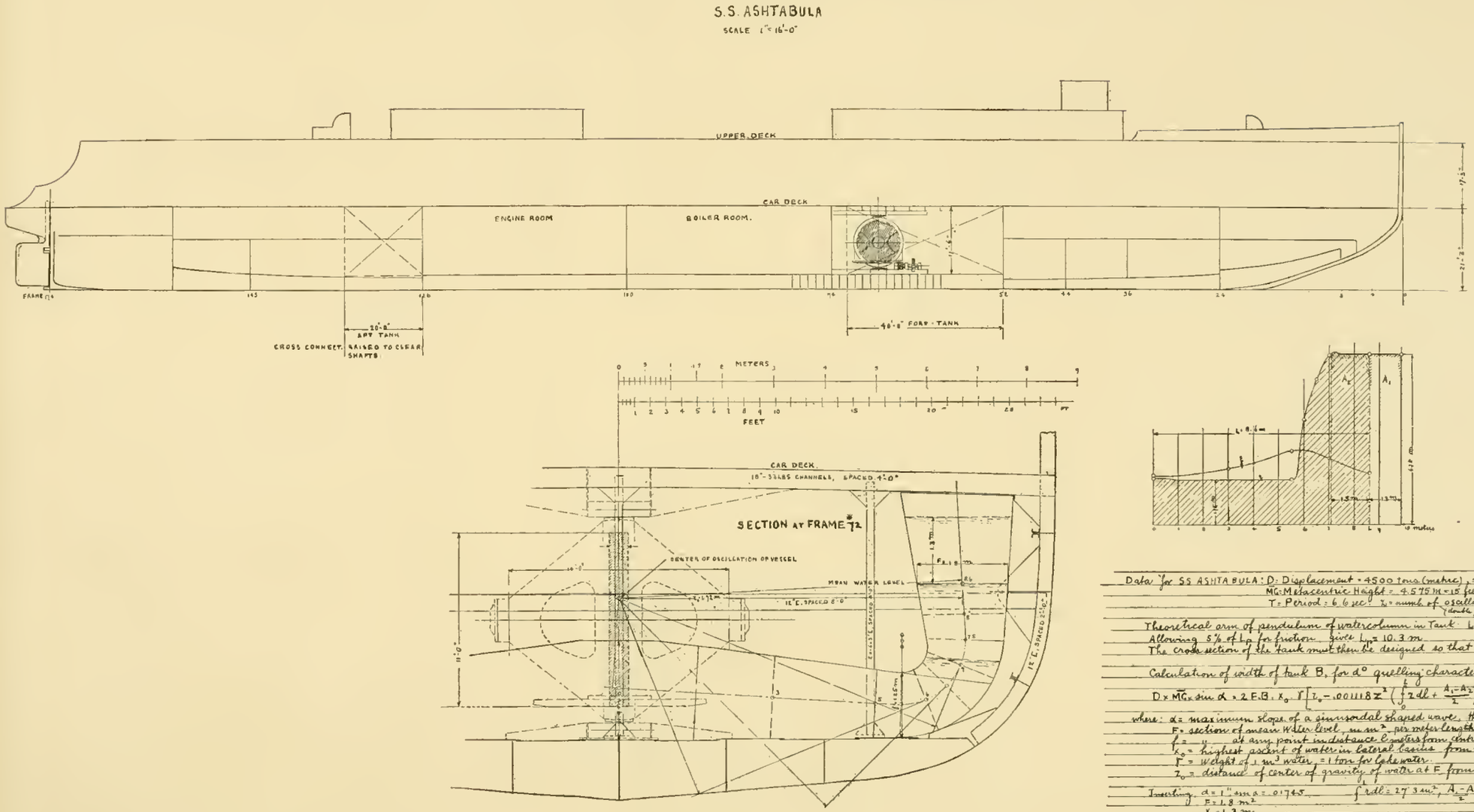


FIG. 14.—S. S. ASHTABULA (PERIOD 6.6).

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

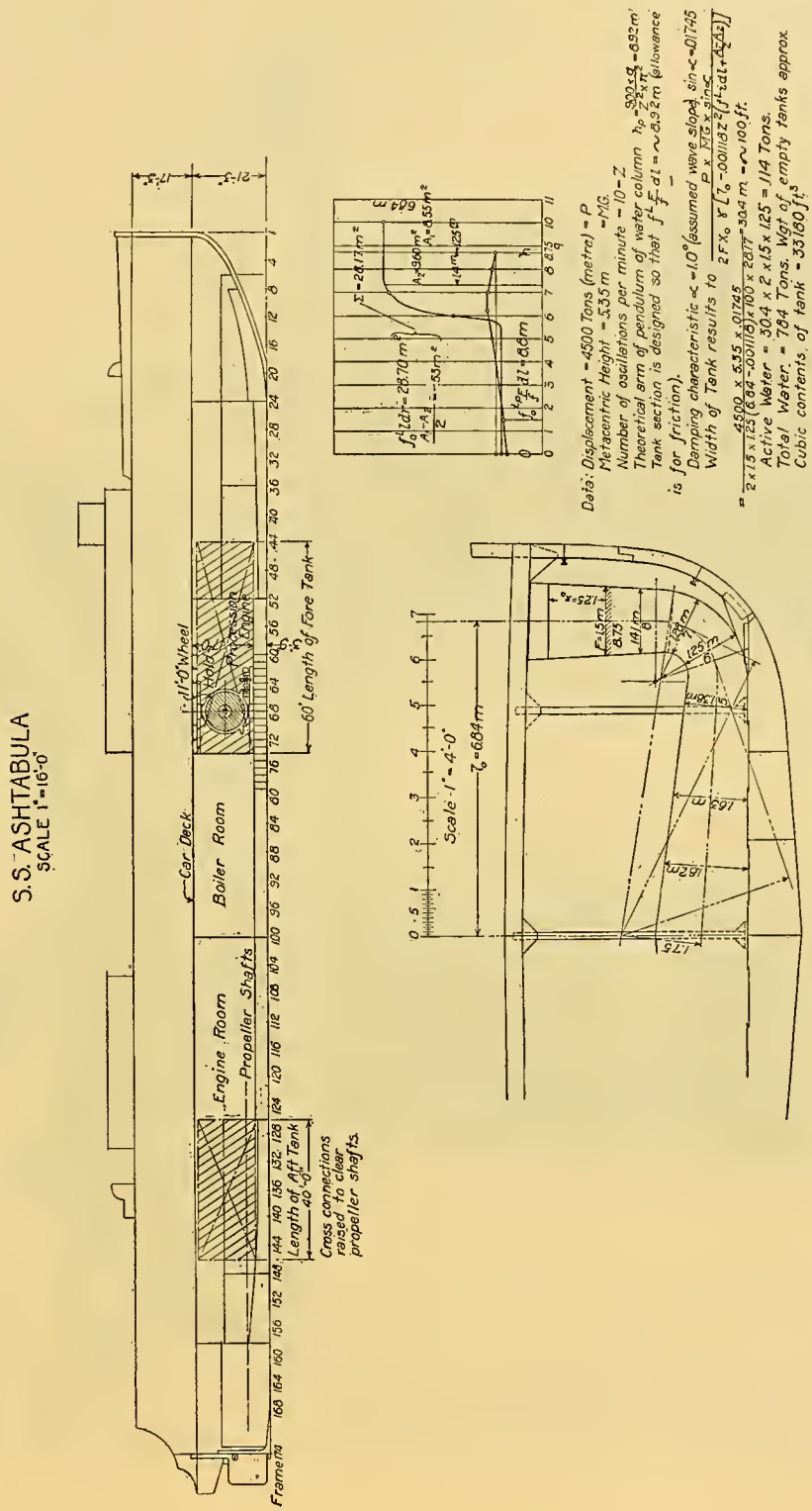


FIG. 15.—S. S. ASHTABULA (PERIOD 6.0).

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

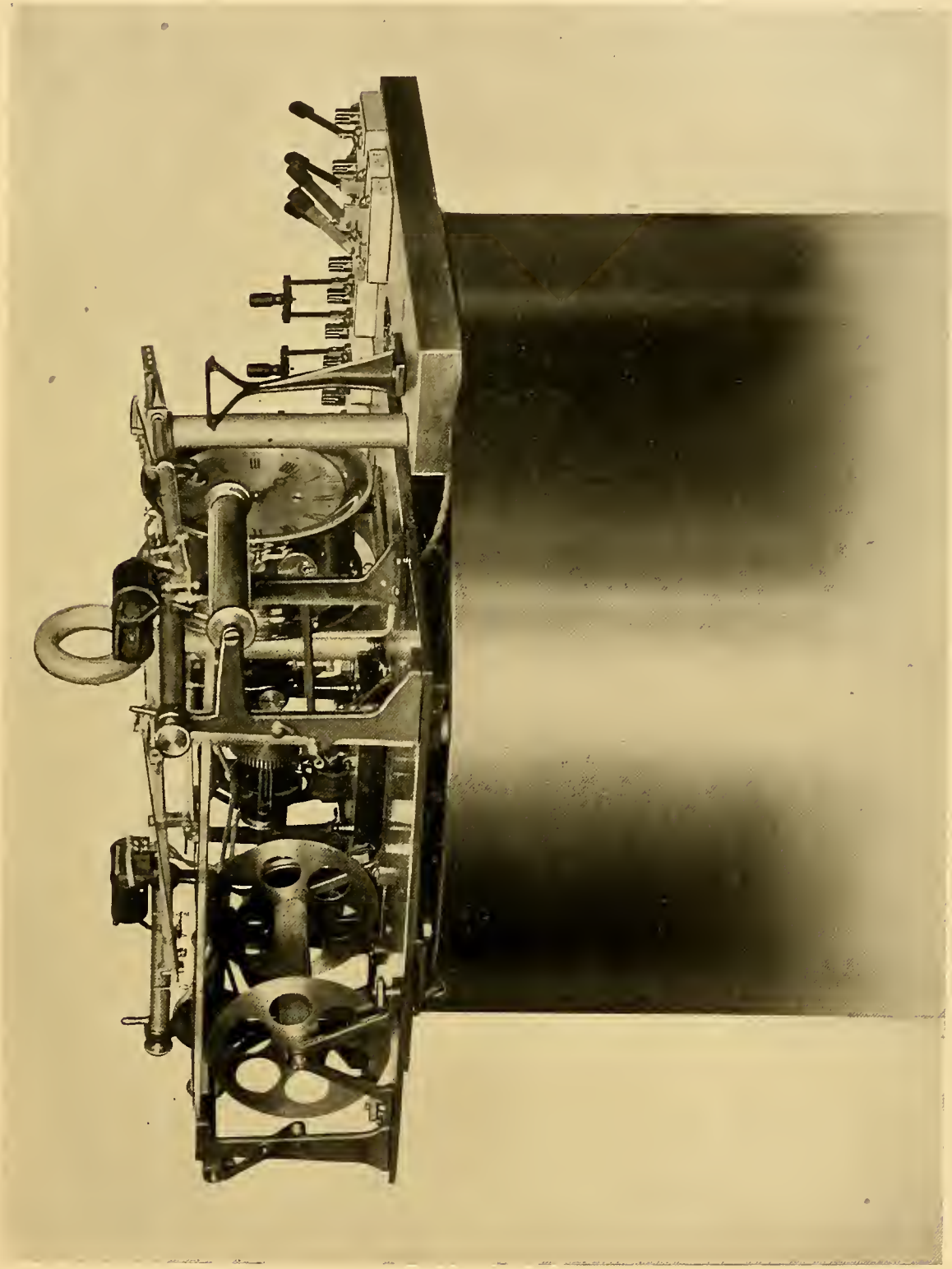


Fig. 16.—Roll and Pitch Recorder with Provision for Base Line, Timing the Records and Spotting Selective Positions in the Curves Themselves.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

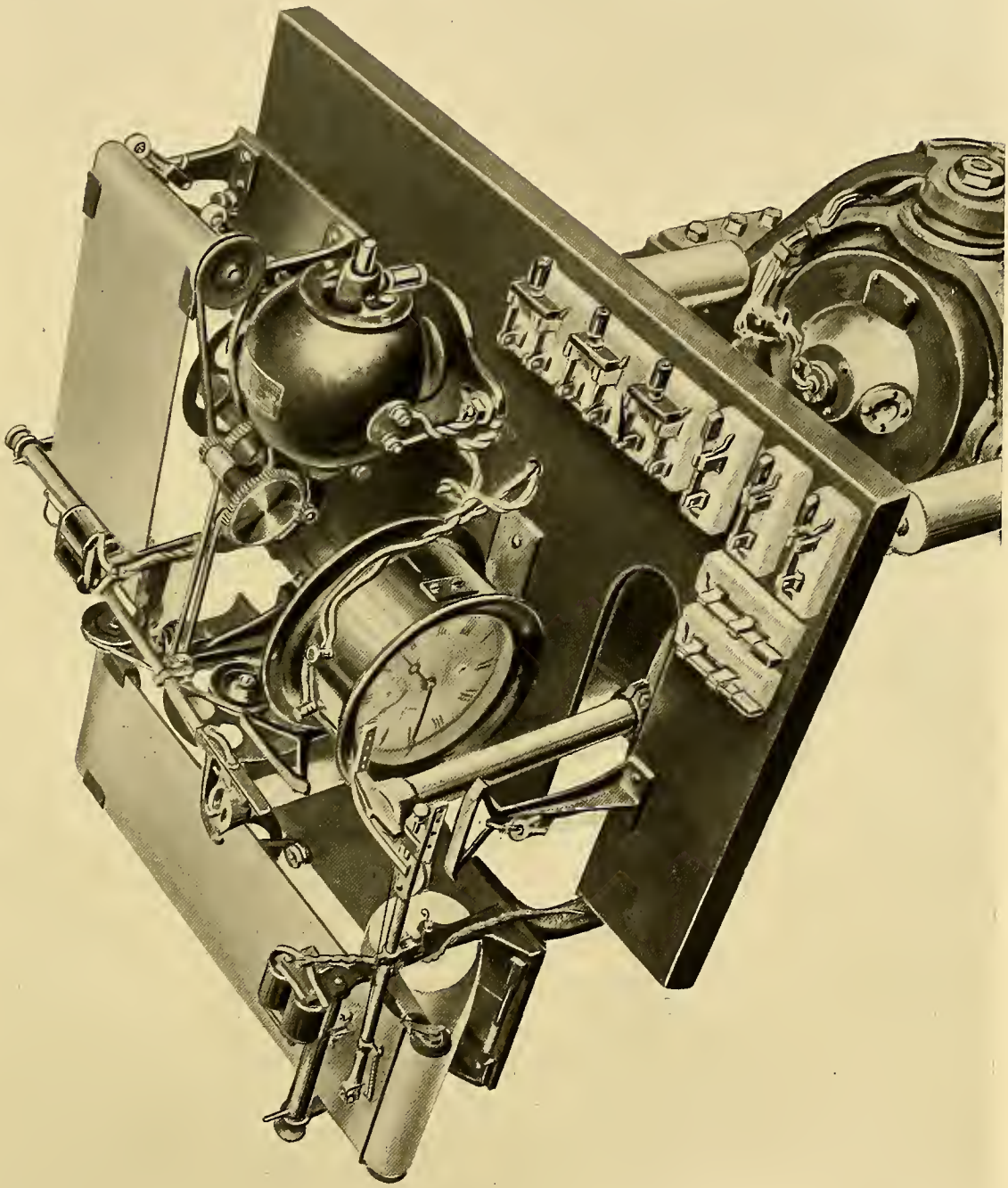


Fig. 17.—Same as Figure 16, Taken from Another Position.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

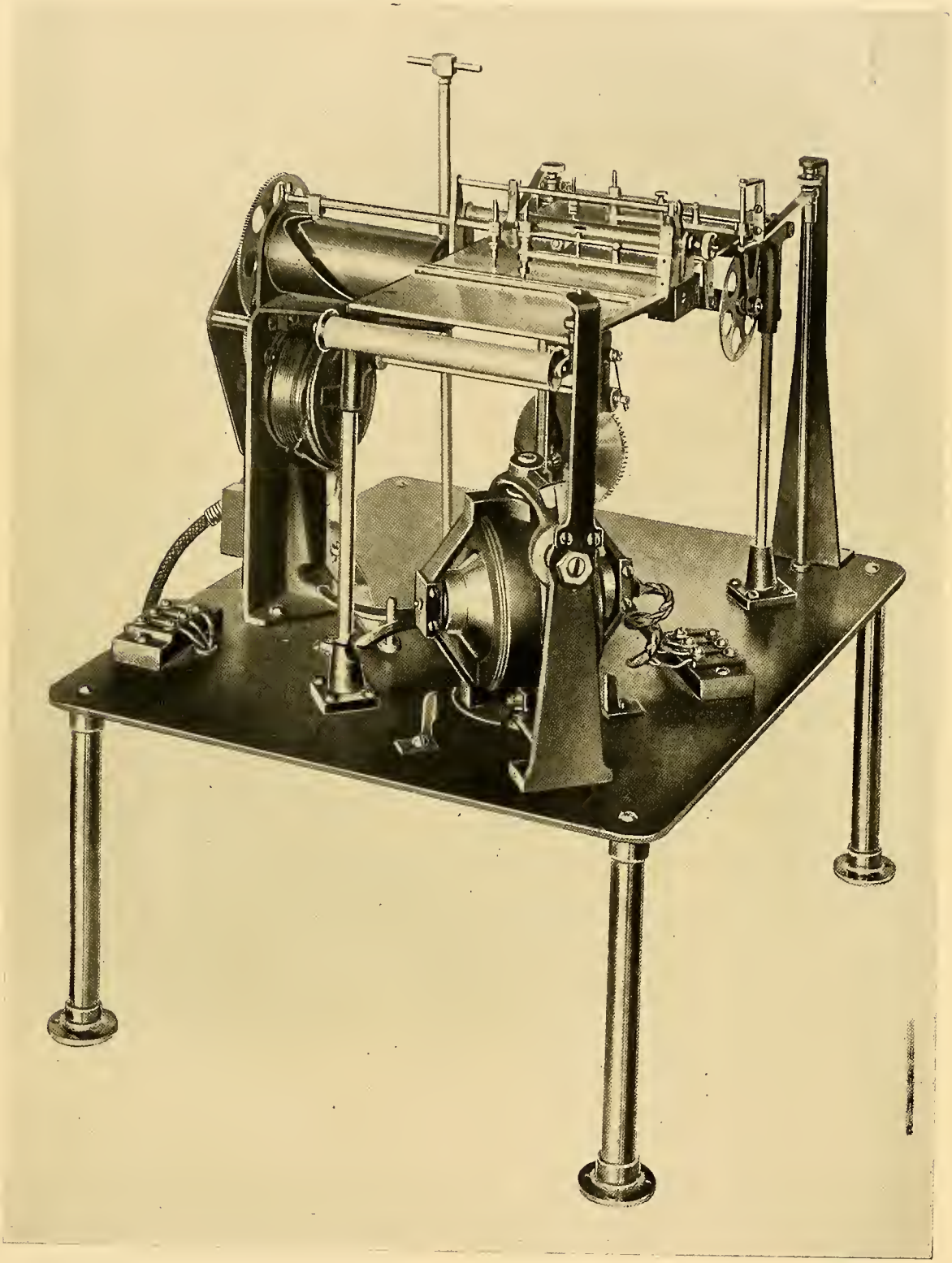


Fig. 18.—Similar Apparatus for Making Six Independent Records upon the Same Tape, as follows: Roll, Pitch, Spotting, Spotting the Roll Curve, Timing and Azimuth of Ship's Heading.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

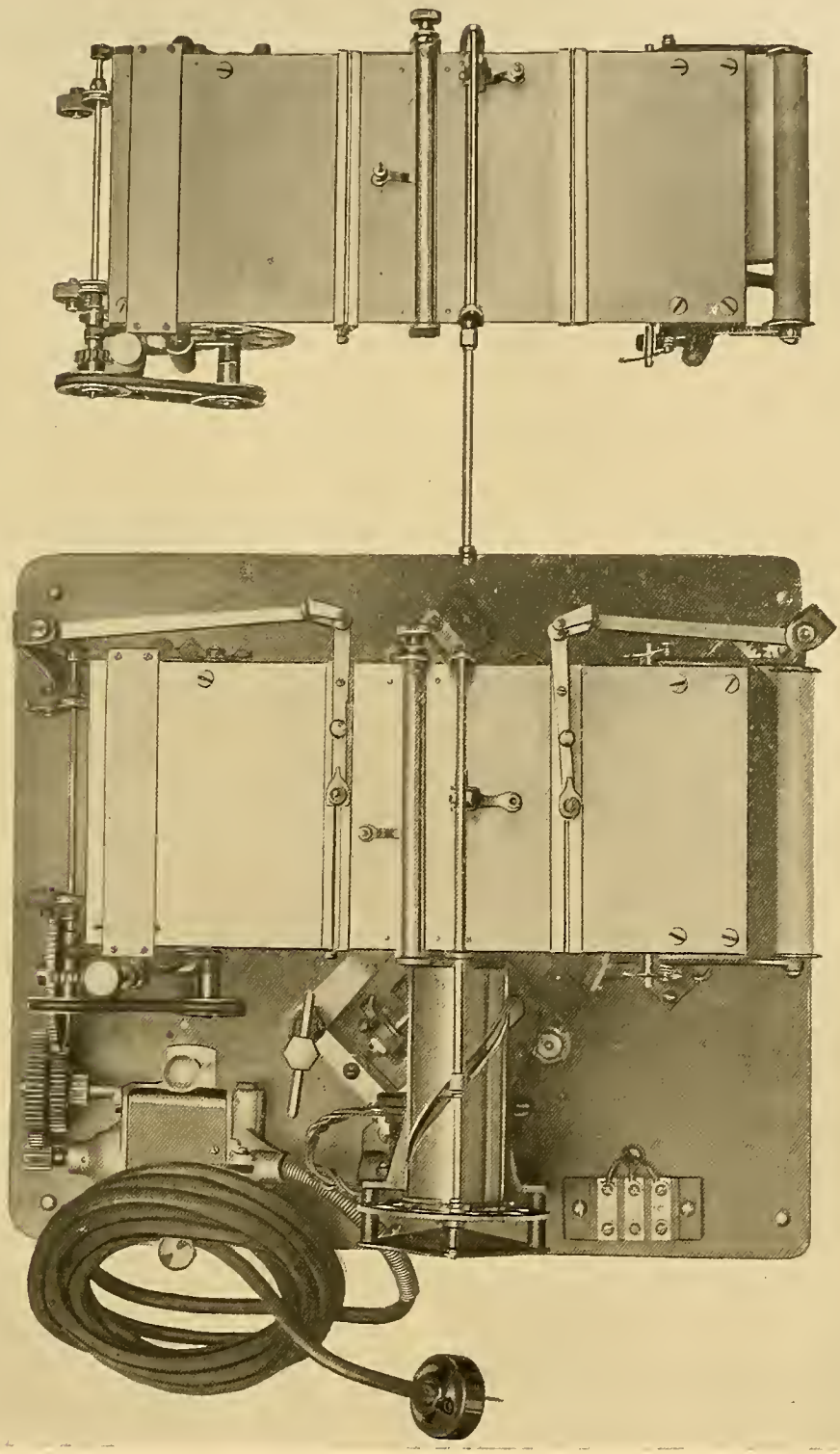


Fig. 19.—Same as Figure 18, Taken from Another Position.

To illustrate paper on "Active Type of Stabilizing Gyro," by Elmer A. Sperry, Esq., Member.

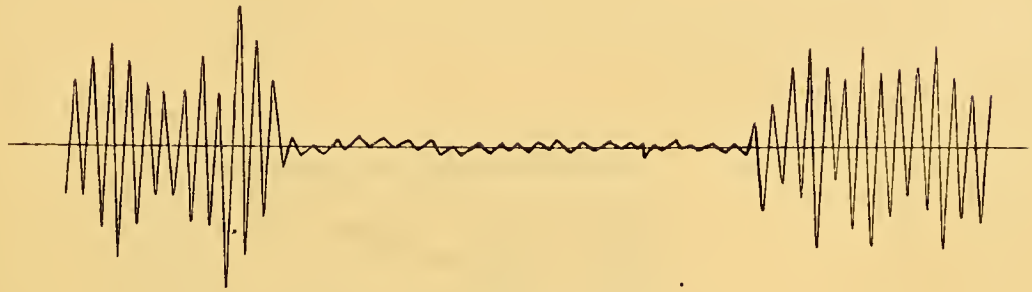


Figure No 20
Gyroscopic Stabilization

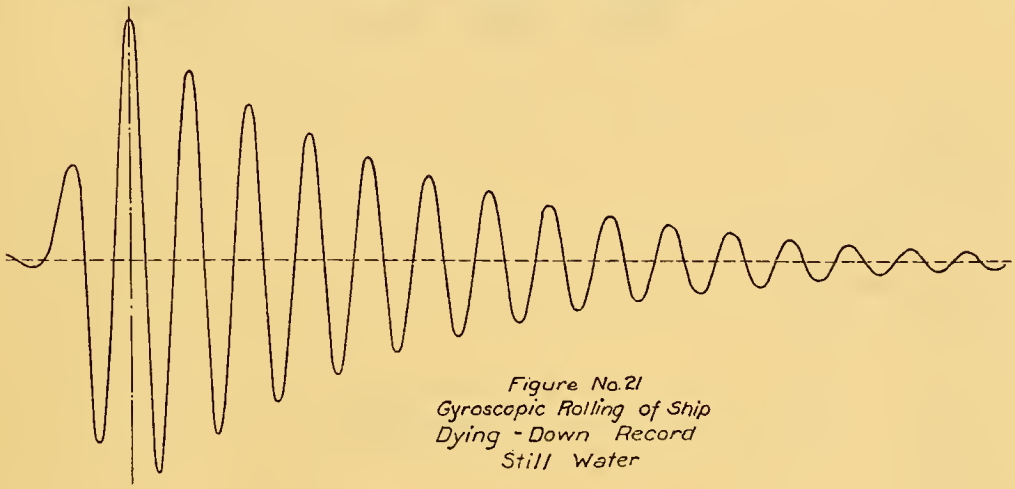


Figure No. 21
Gyroscopic Rolling of Ship
Dying - Down Record
Still Water

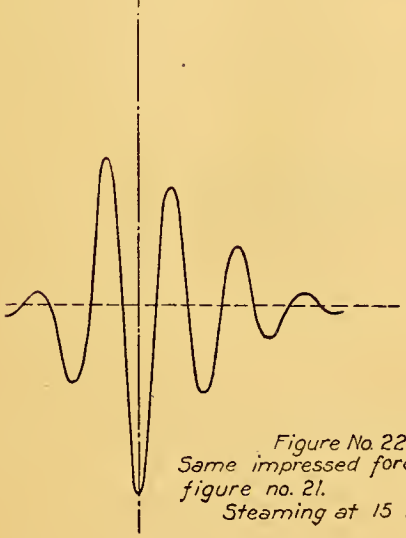


Figure No. 22
Same impressed forces as in figure no. 21.
Steaming at 15 knots.

To illustrate paper on "Notes on Fuel Economy as Influenced by Ship Design," by E. H. Rigg, Esq., Member.

COMPARISON OF PROPERTIES.

	A.	B.
BEAM AT WATERLINE.	43'-0"	45'-0"
DRAFT.	12'-6"	12'-6"
DISPL^T. IN TONS	2230	2260
BLOCK COEFFICIENT	.541	.524
PRISMATIC "	.634	.568
MIDSHIP "	.853	.922
TRANS. K.M. (KEEL TO META:)	18.30'	18.38'

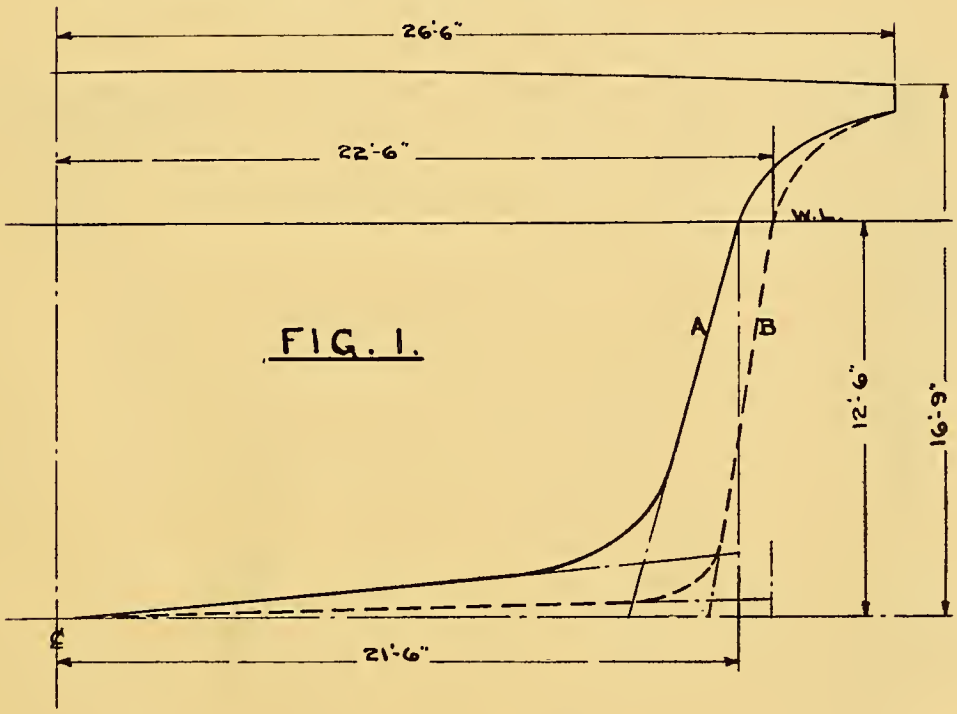


FIG. 1.

To illustrate paper on "Notes on Fuel Economy as Influenced by Ship Design," by E. H. Rigg, Esq., Member.

EXAMPLE NO. 6.

FULL LINES ARE FOR VESSEL 308'-6" × 47'-0" × 20'-9"
DOTTED LINES ARE FOR VESSEL 308'-6" × 46'-0" × 20'-0"
DISPLACEMENT IN EACH CASE IS 5600 TONS SALT WATER

EXAMPLE NO. 6

COMPARATIVE TABLE OF EFFECTIVE HORSE POWERS.

SPEED	308'-6" × 46'-0" × 20'-0"		308'-6" × 47'-0" × 20'-9"	
	EVEN KEEL	24" TRIM BY STERN	EVEN KEEL	24" TRIM BY STERN
6	121	121	131	131
7	190	193	199	199
8	279	289	288	288
9	393	410	401	401
10	543	566	544	544
11	734	757	710	710
12	975	1012	921	921
13	1313	1347	1223	1223
14	1900	1860	1754	1754
15	2420	2365	2152	2152

FIGURE 2.

EXAMPLE NO. 6.

COMPARATIVE BODY PLANS.

SCALE $\frac{1}{4}$" = 1 FOOT.

STATIONS SPACED 15'-0" APART
STA. *20 — 7'-9" FROM AFTER PERPENDICULAR.

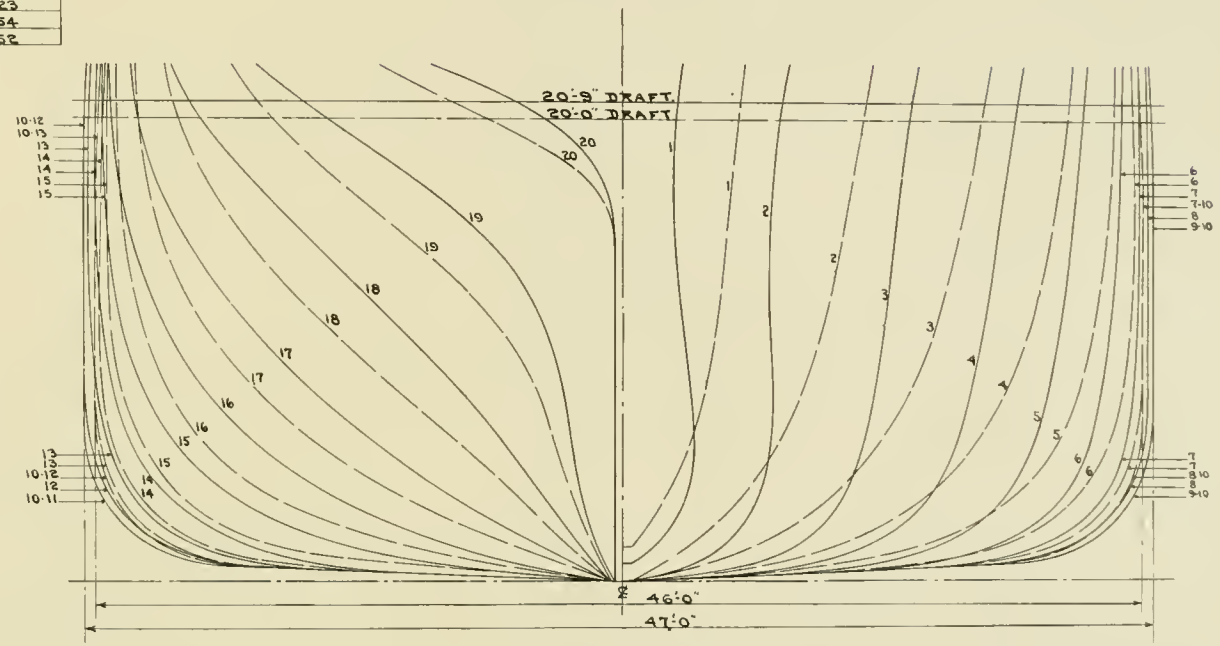


FIGURE 3.

To illustrate paper on "Developments in Oil Burning," by E. H. Peabody, Esq., Member.

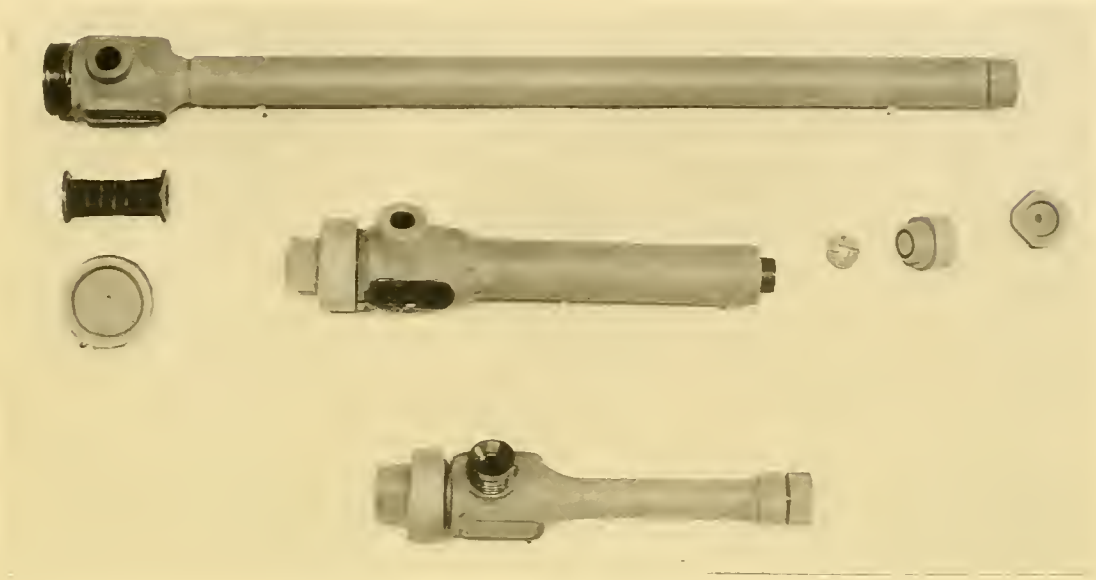


Fig. 9.—Peabody Mechanical Atomizer.

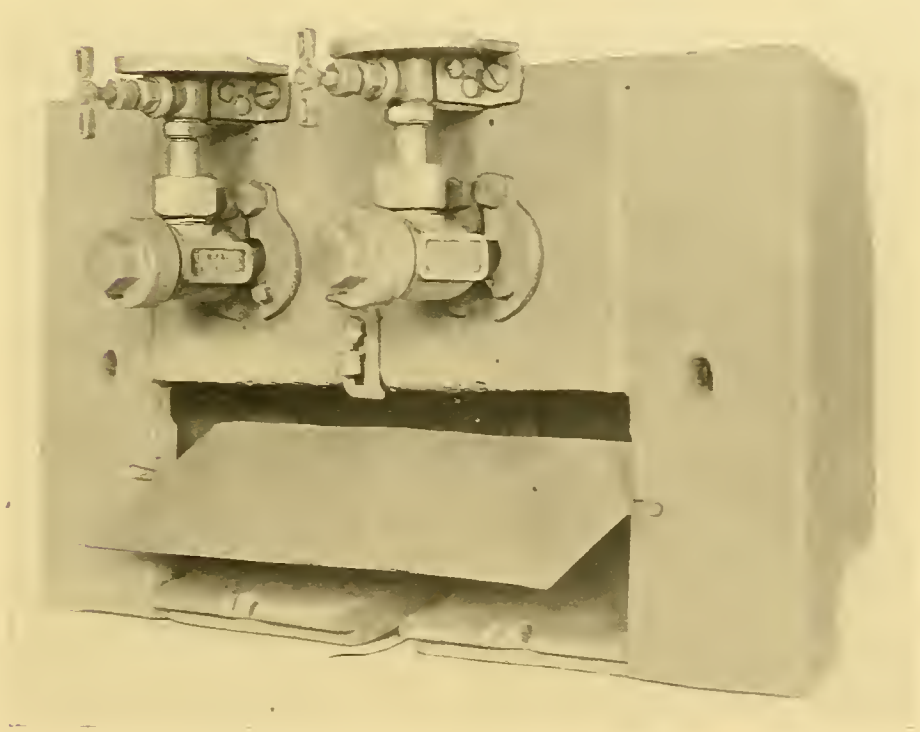


Fig. 12.—Fitting of Oil Burners for Coal and Oil—Front.

To illustrate paper on "Developments in Oil Burning," by E. H. Peabody, Esq., Member.

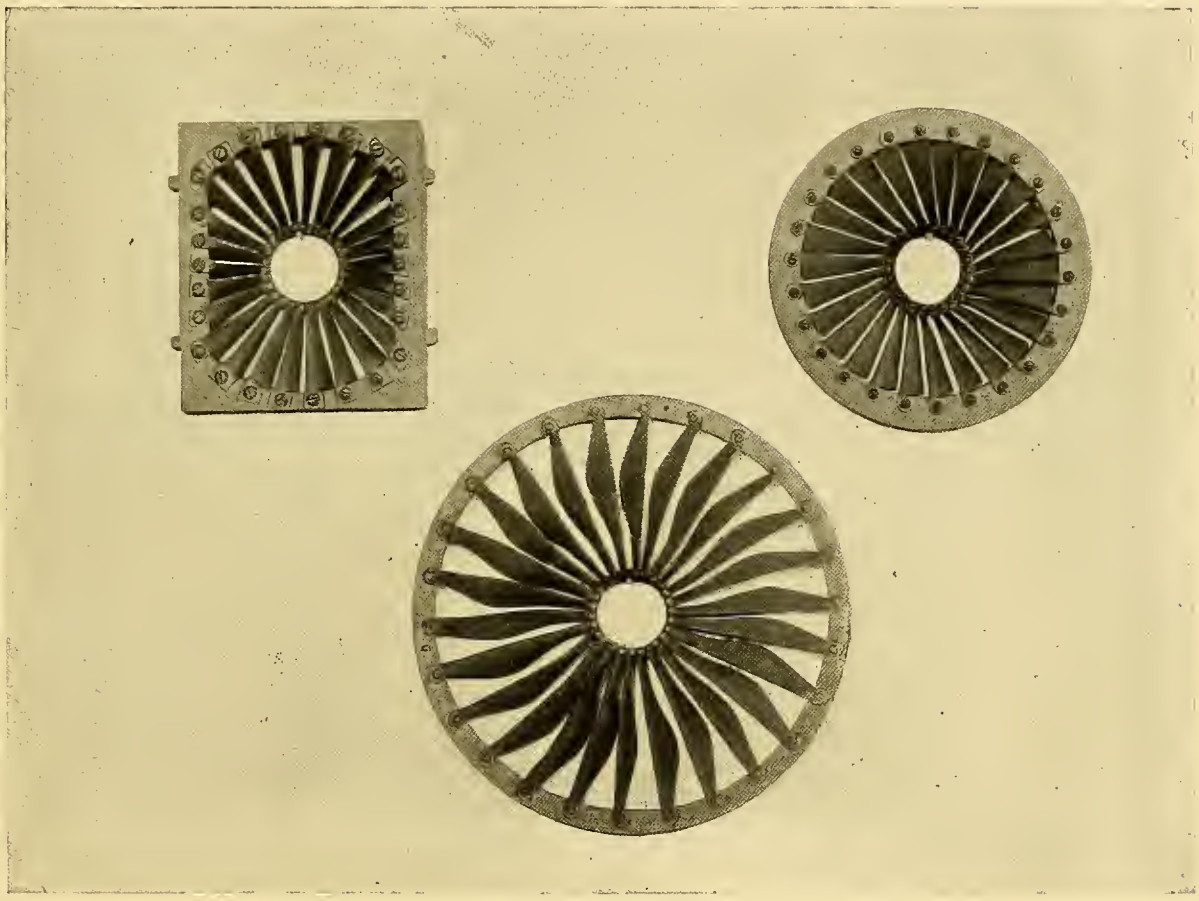


FIG. 11.—IMPELLER PLATES.

To illustrate paper on "Developments in Oil Burning," by E. H. Peabody, Esq., Member.

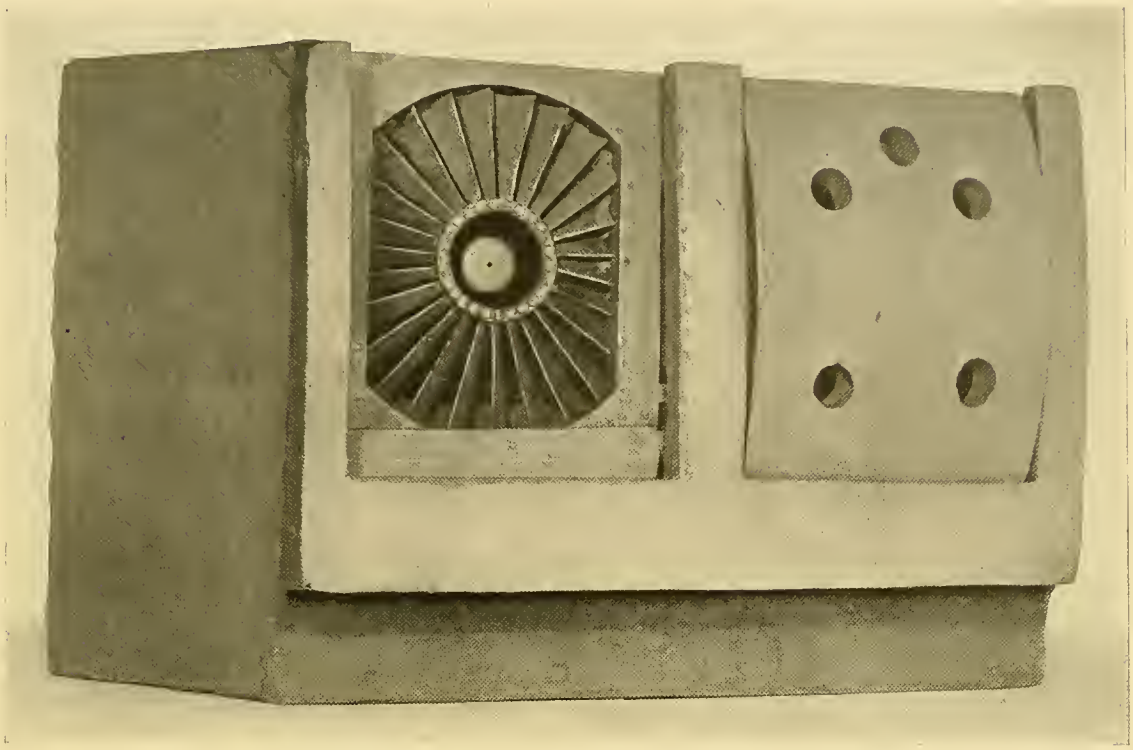


FIG. 13.—FITTING OF OIL BURNERS FOR COAL AND OIL—REAR.

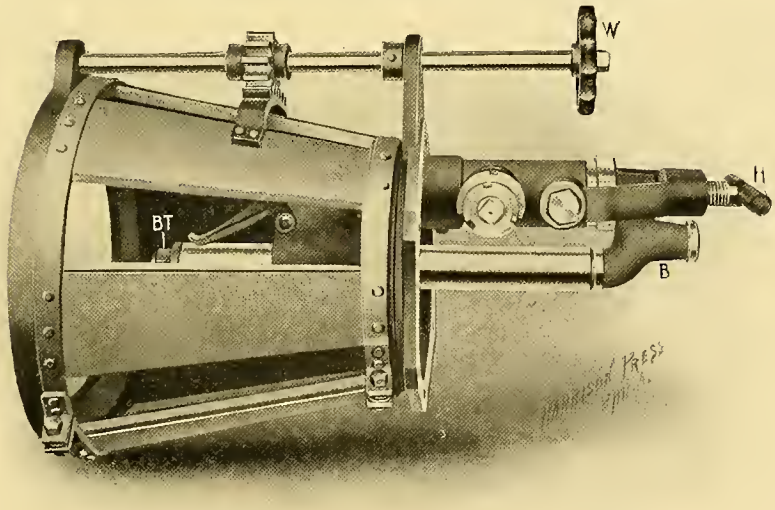


FIG. 36.

To illustrate paper on "Developments in Oil Burning," by E. H. Peabody, Esq., Member.

Fig. 14.—Babcock & Wilcox Boiler—U. S. S. Wyoming, Showing Oil Burners in Combination with Coal.

To illustrate paper on "Developments in Oil Burning," by E. H. Peabody, Esq., Member.

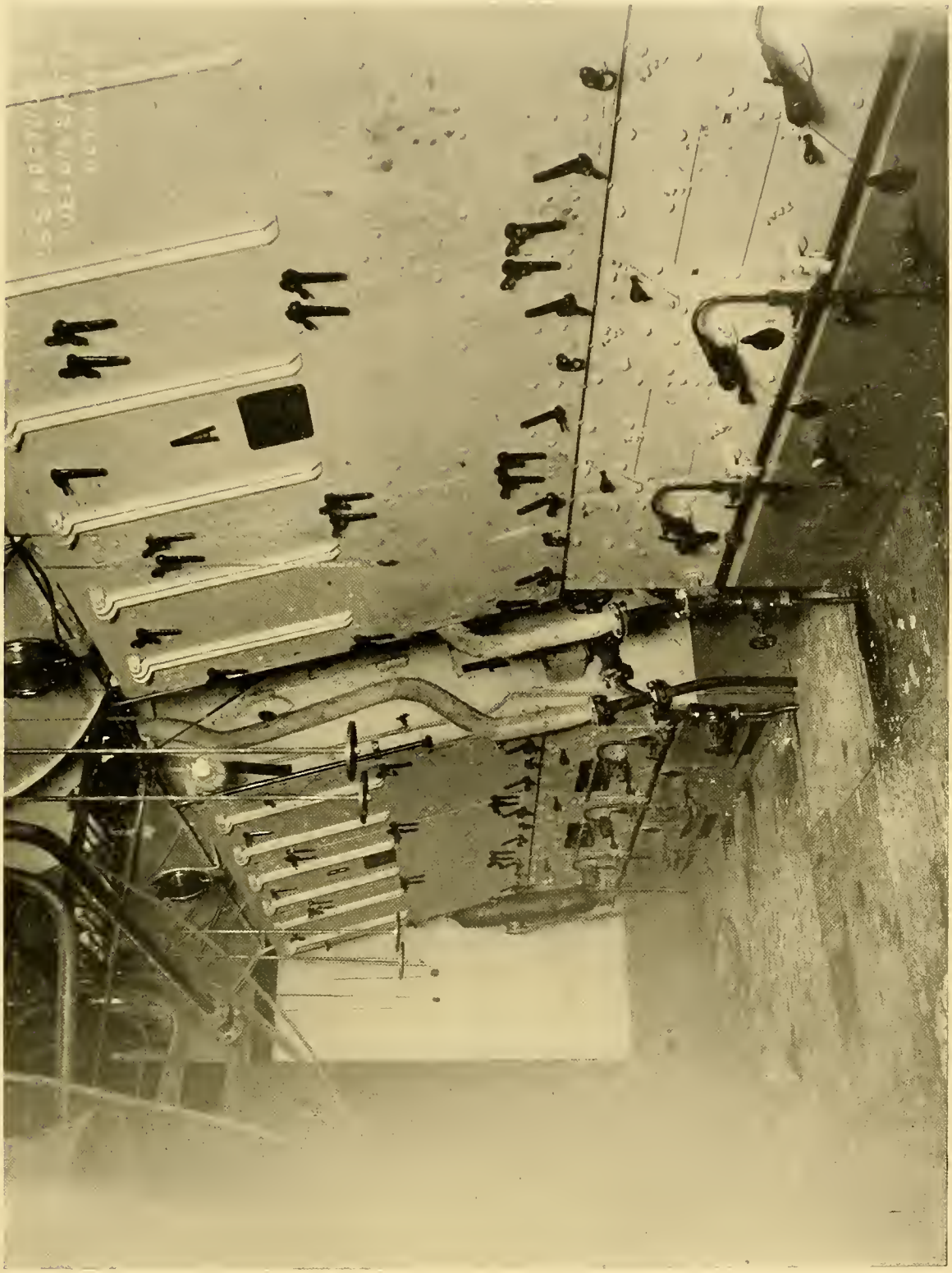


Fig. 15.—U. S. S. Arethusa. Fuel Oil System.

To illustrate paper on "The Sperry Gyro-Compass in Service," by R. E. Gillmor, Esq., Associate.

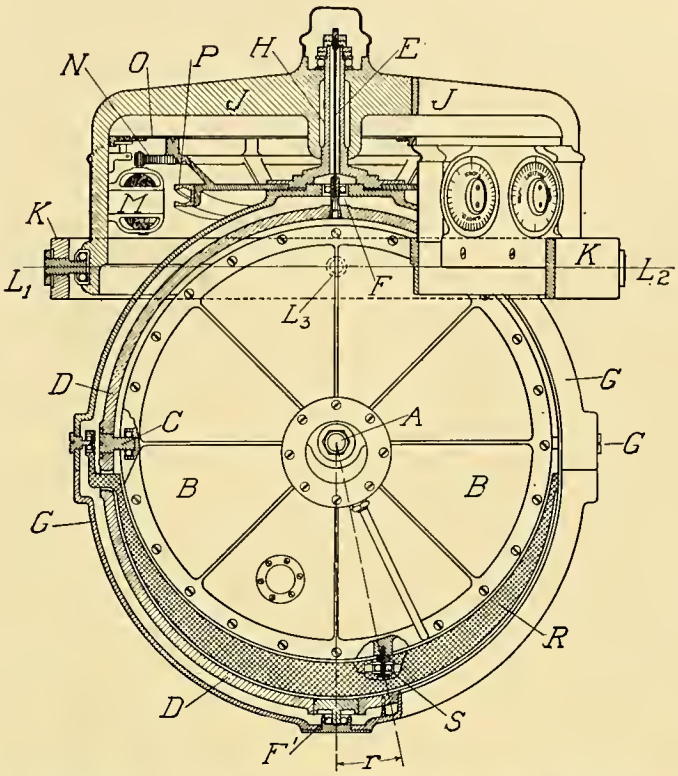


Fig. 1.—Section of Compass in the Plane of the Gyro Wheel.

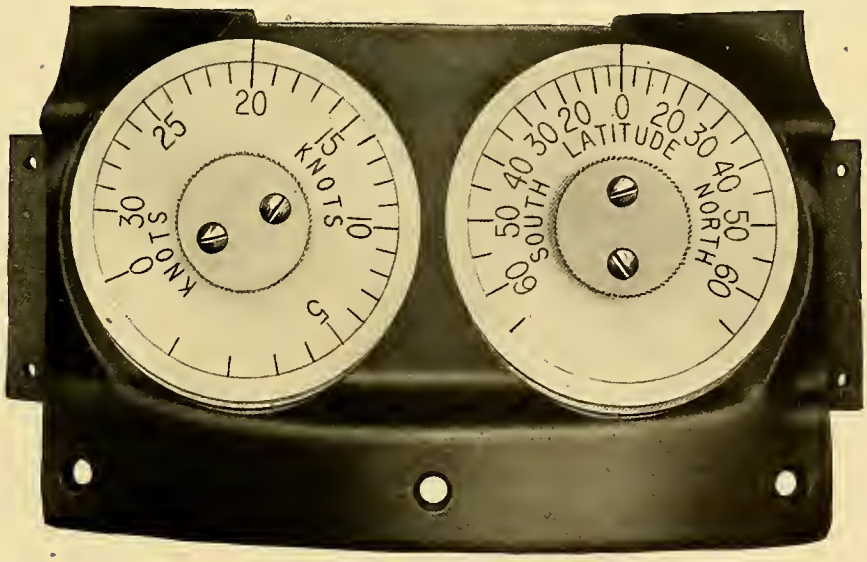


Fig. 2.—Correction Device.

To illustrate paper on "The Sperry Gyro-Compass in Service," by R. E. Gillmor, Esq., Associate.

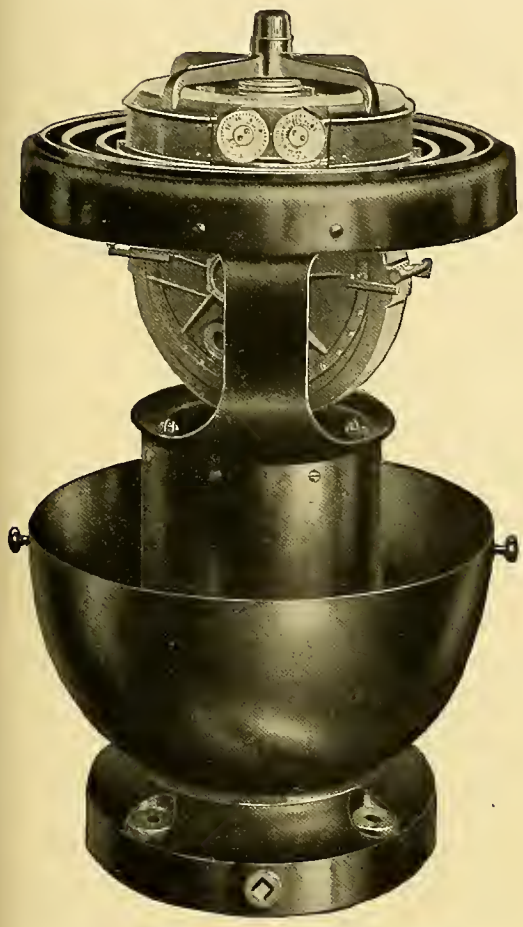


Fig. 3.—Instrument with Covers Removed.

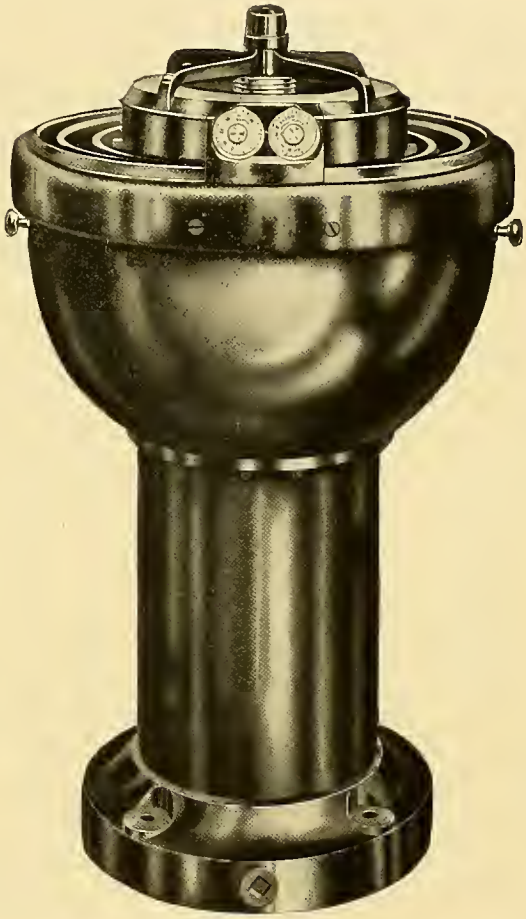


Fig. 4.—Master Compass, Top Cover Removed.

To illustrate paper on "The Sperry Gyro-Compass in Service," by R. E. Gillmor, Esq., Associate.

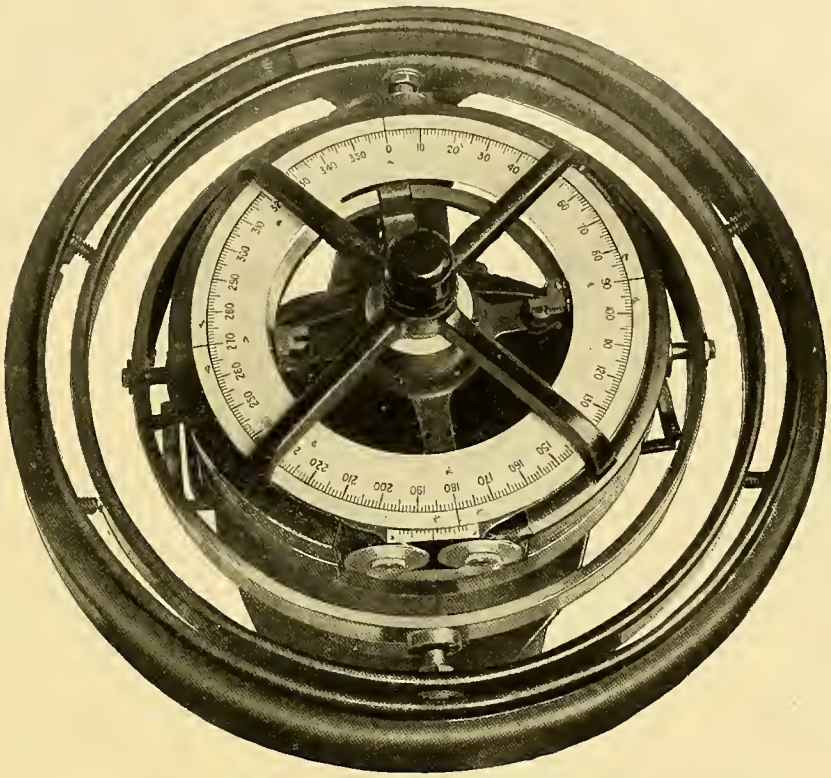


Fig. 5.—Master Compass, Top View.

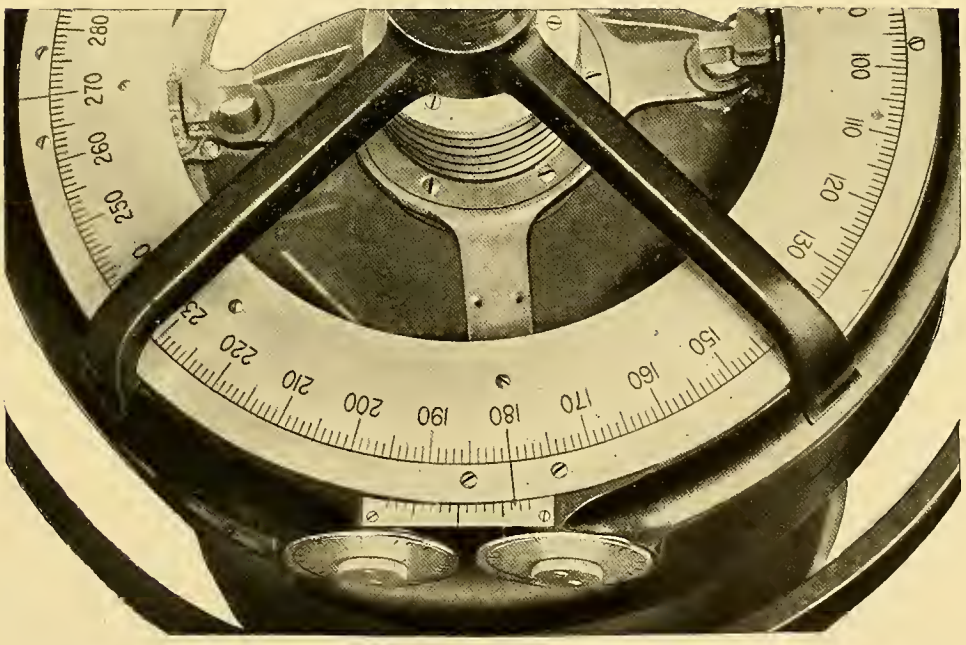


Fig. 6.—Master Compass, Top View, Correction Device.

To illustrate paper on "The Sperry Gyro-Compass in Service," by R. E. Gillmor, Esq., Associate.

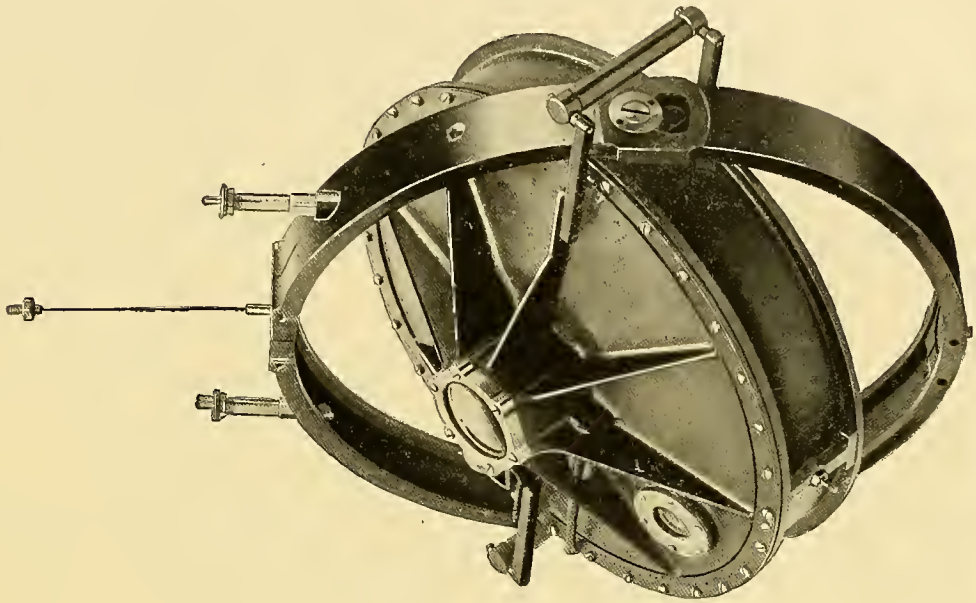


Fig. 7.—Wheel Casing and Vertical Cardan Ring.

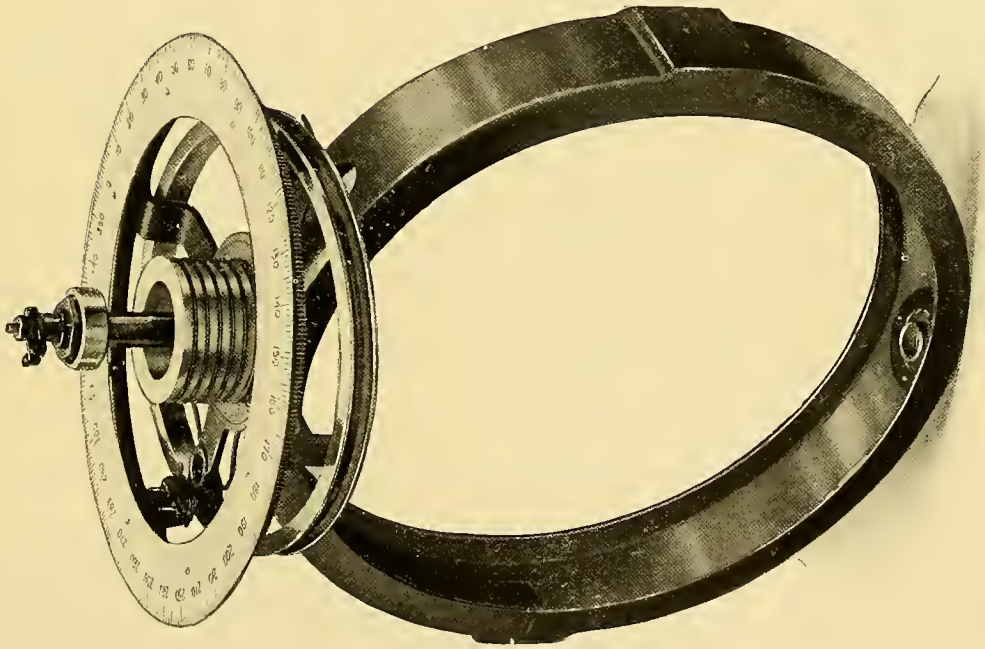


Fig. 9.—Phantom Ring.

To illustrate paper on "The Sperry Gyro-Compass in Service," by R. E. Gillmor, Esq., Associate.

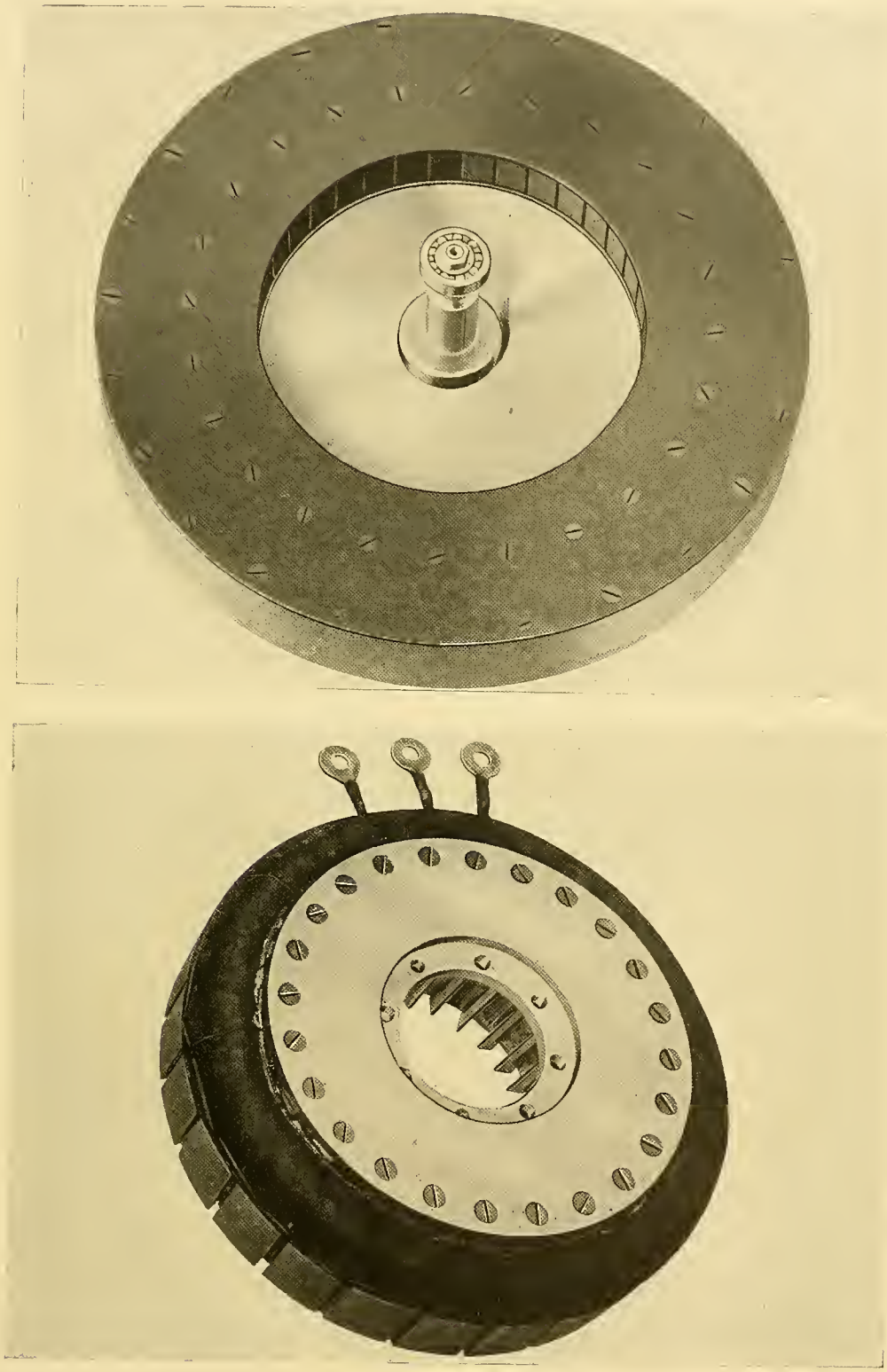


Fig. 8.—Gyro Wheel and Stator.

To illustrate paper on "The Sperry Gyro-Compass in Service," by R. E. Gillmor, Esq., Associate.

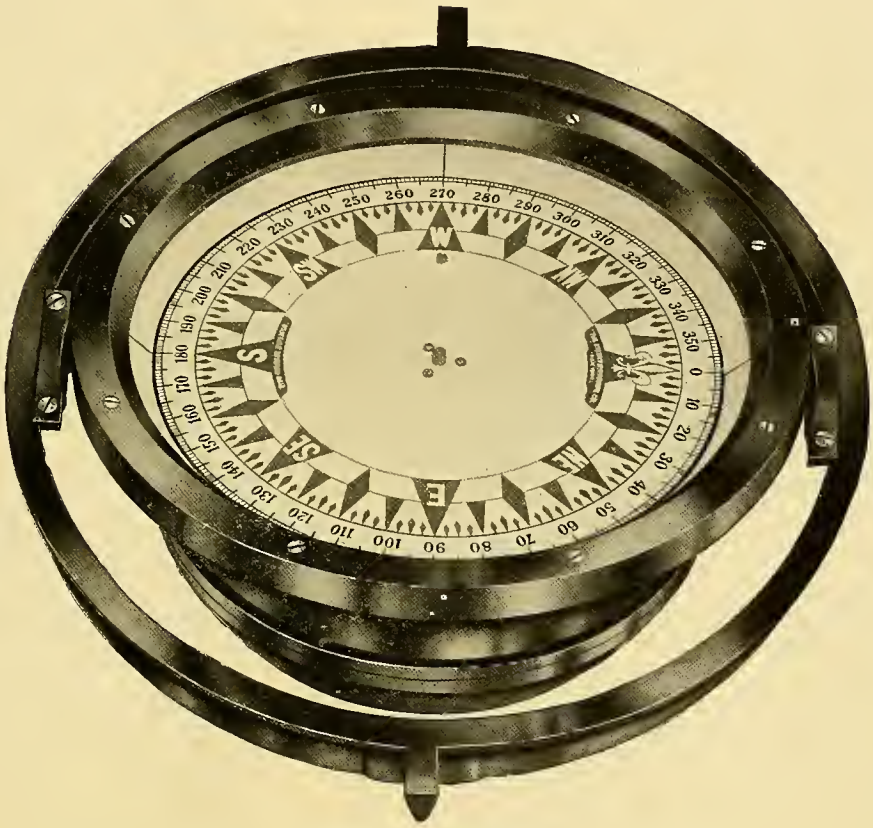


Fig. 10.—Repeater.

To illustrate paper on "The Sperry Gyro-Compass in Service," by R. E. Gillmor, Esq., Associate.

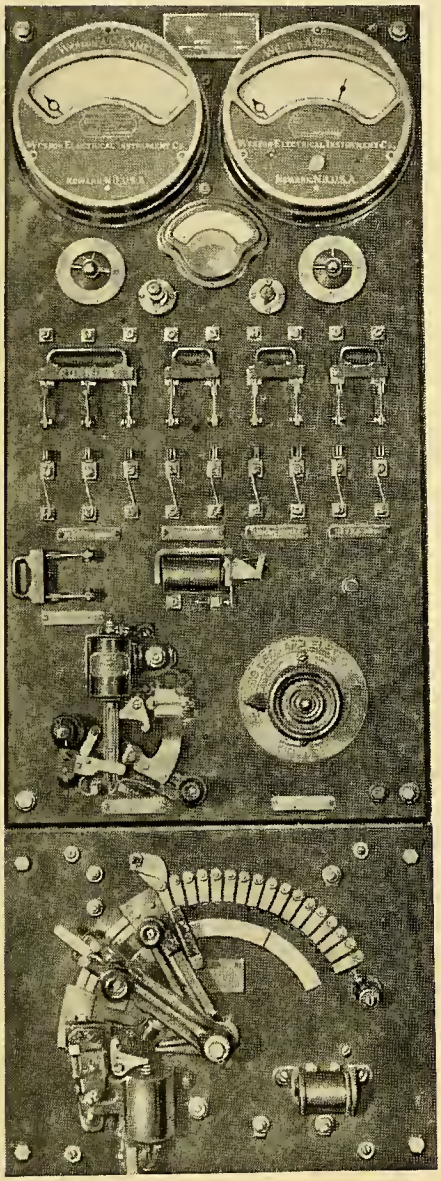


FIG. 11.—ENERGY SWITCHBOARD.

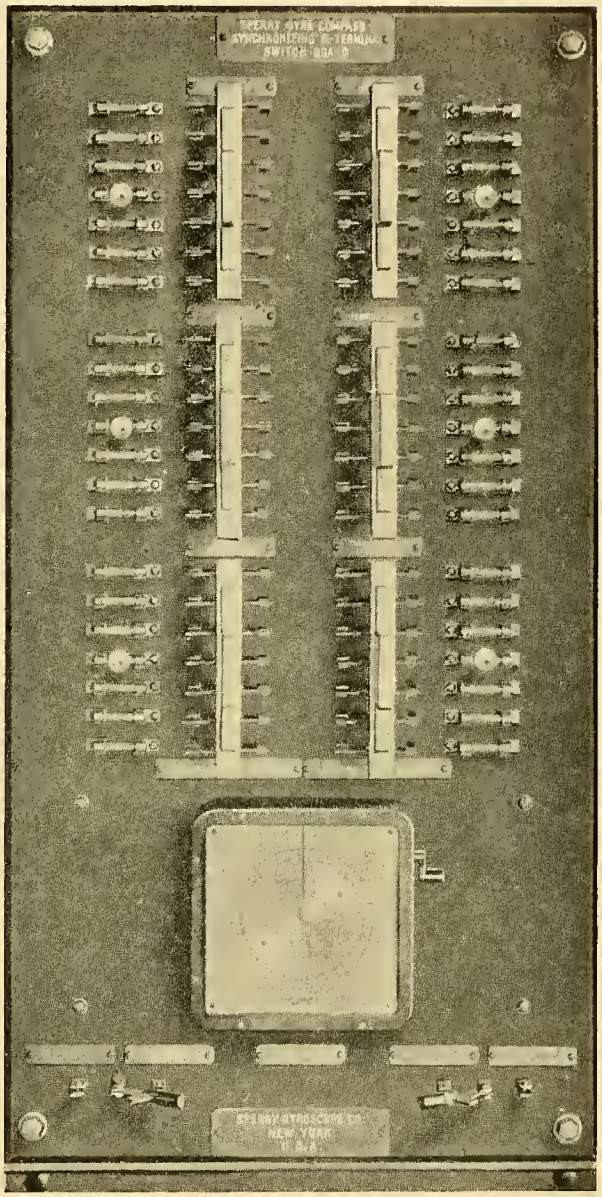


FIG. 12.—REPEATER SWITCHBOARD.

To illustrate paper on "The Sperry Gyro-Compass in Service," by R. E. Gillmor, Esq., Associate.

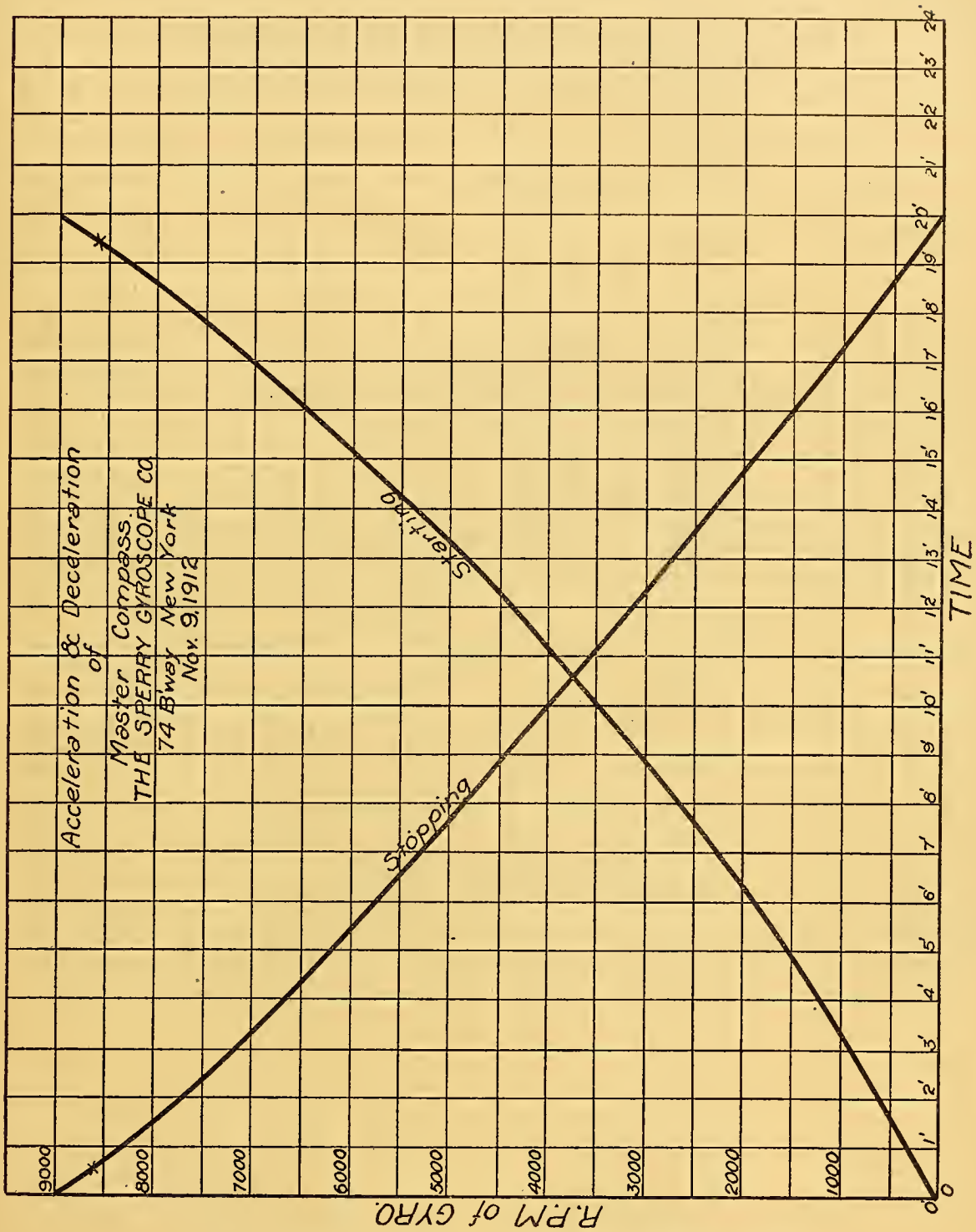


FIG. 13.—STARTING CURVE OF COMPASS—TIME AND SPEED OF WHEEL.

To illustrate paper on "The Sperry Gyro-Compass in Service," by R. E. Gillmor, Esq., Associate.

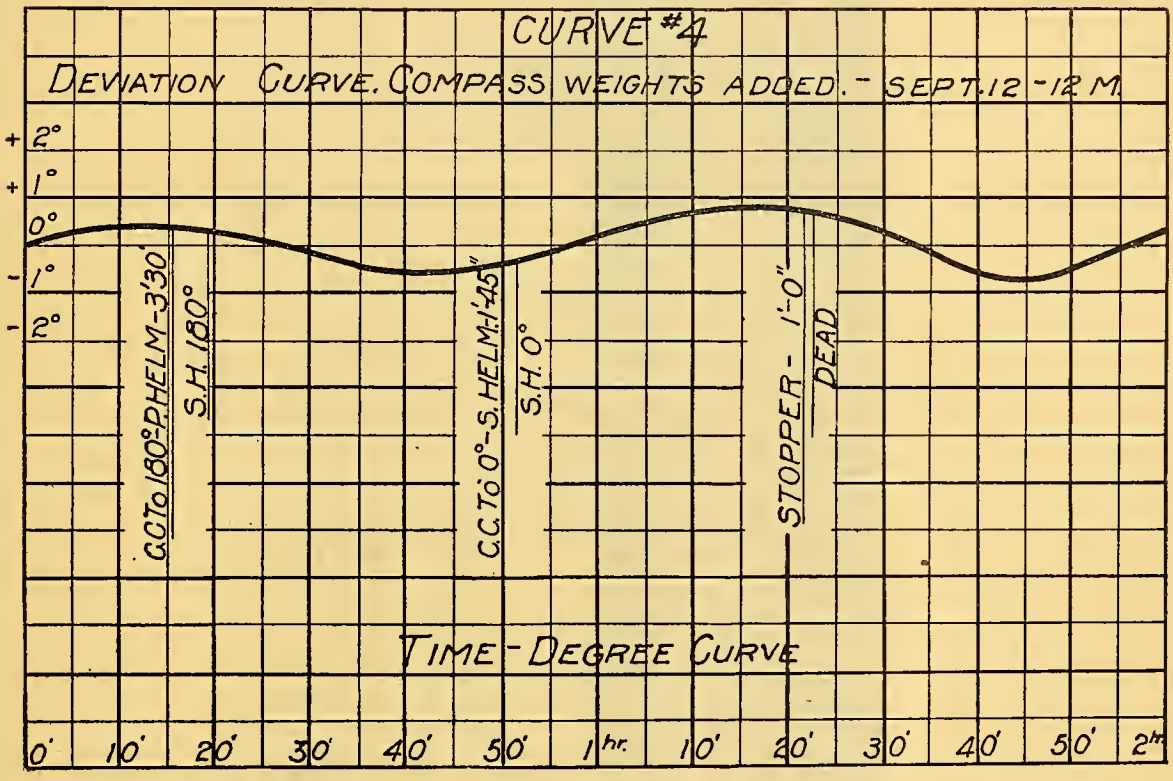
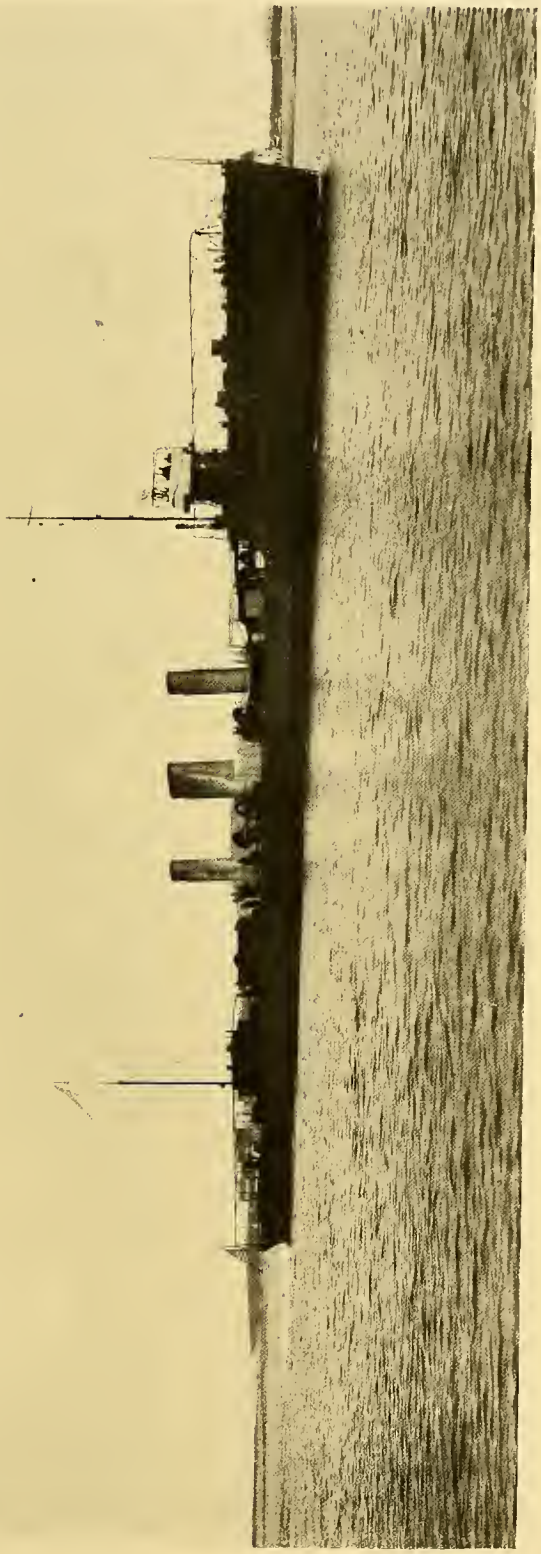


FIG. 17.—CURVES OF OSCILLATIONS CAUSED BY MOVEMENTS OF THE SHIP IN CHANGING SPEED AND COURSE.

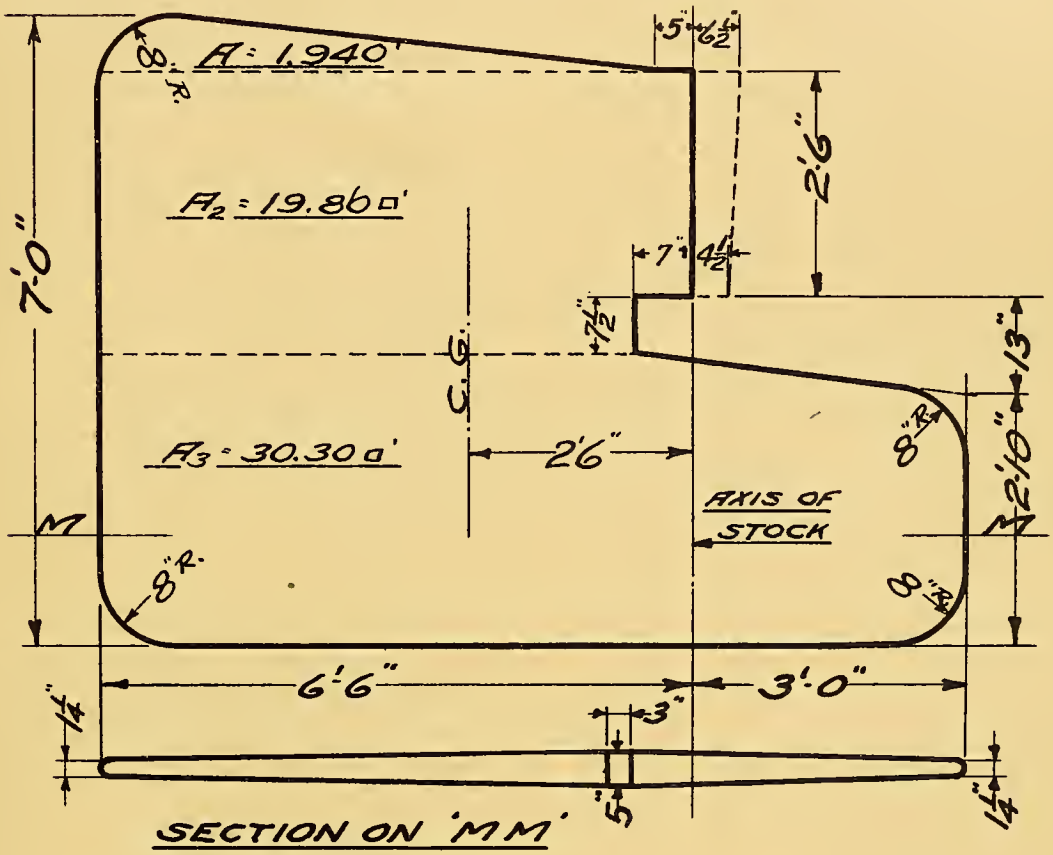
To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.



U. S. S. STERETT.

To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

FIGURE 1.

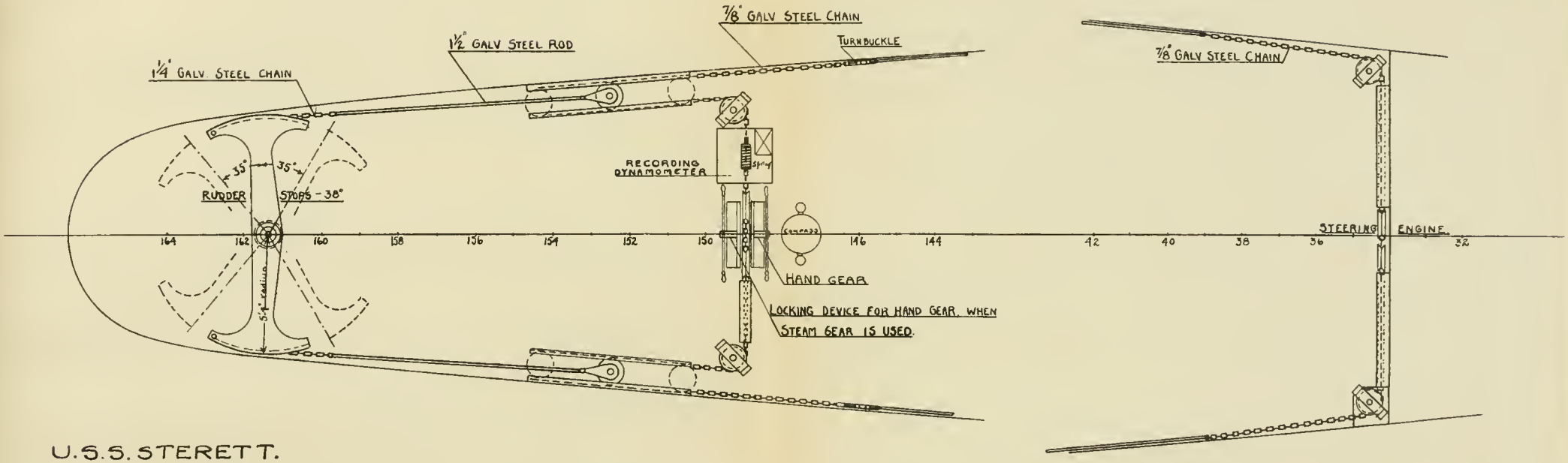


RUDDER OF U.S.S. STERETT
AREA FOR COMPUTATIONS OF STRESS
SCALE ½" = 1 FT.
TOTAL AREA RUDDER = 52.10 □' = A
RATIO = $\frac{\text{AREA}}{L \times D} = \frac{52.10}{289.0 \times 8.33} = \frac{1}{46}$
RADIUS OF YOKE = 5'-4"
DIAMETER OF RUDDER POST
OUTER 9¼"
INNER 4"
C.G. OF RUDDER 2.50' ABAFT AXIS OF STOCK
C.G. OF SHIP 135.46' FORWARD AXIS OF STOCK

Transactions Society Naval Architects and Marine Engineers, Vol. 20, 1912.

To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

FIGURE 2.



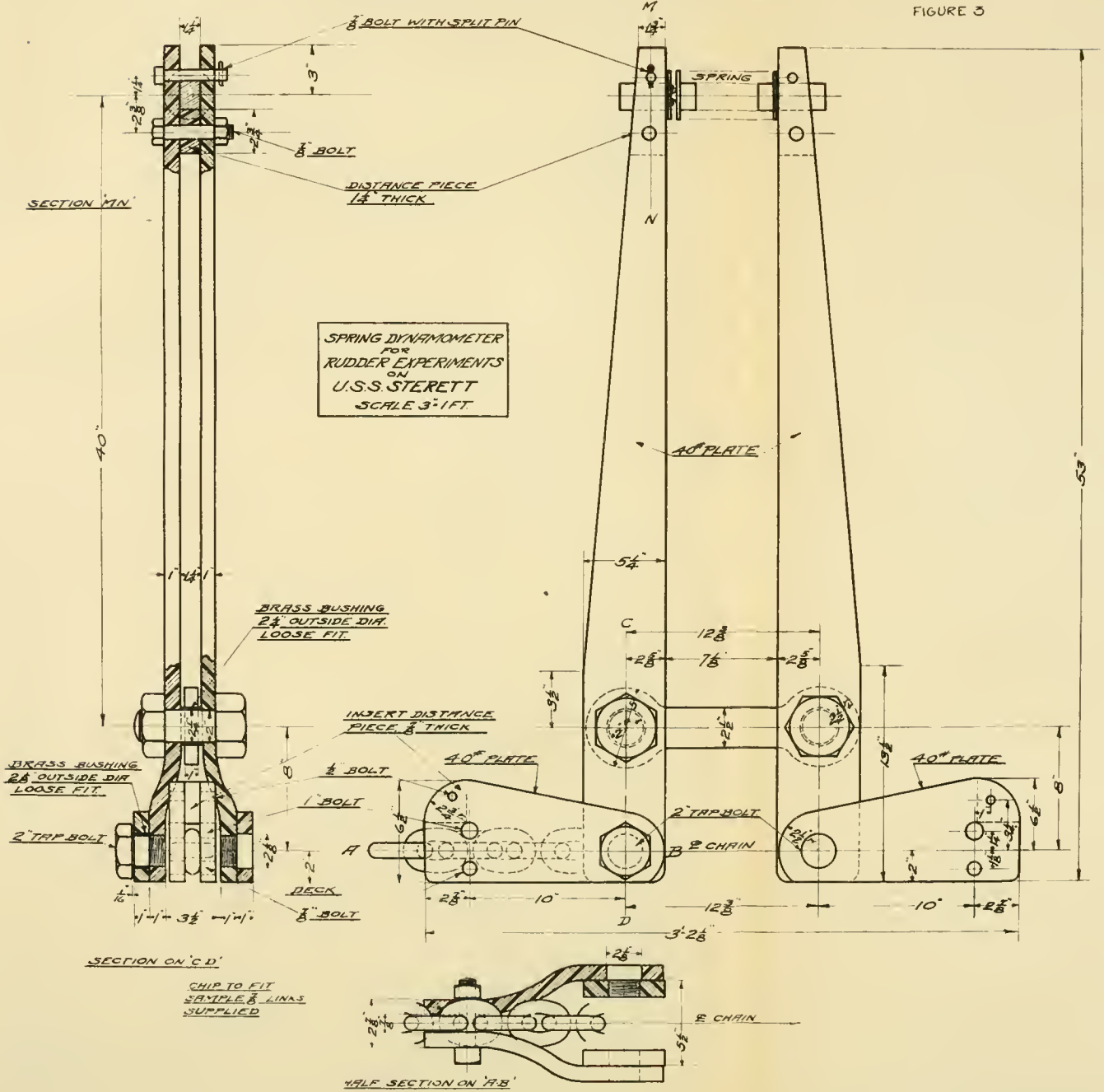
U.S.S. STERETT.
GENERAL ARRANGEMENT OF
STEERING GEAR
SCALE ¼" = 1 FT

STEERING WHEEL 3' DIA, 9.83 TURNS FROM HARD OVER TO HARD OVER.
VERTICAL DOUBLE CYLINDER 5" x 5" LIDGERWOOD
STEAM STEERING ENGINE, - 3.9 TURNS OF
CHAIN WHEEL FROM H.O TO H.O.

THE NORRIS PETERS CO. WASHINGTON D.C.

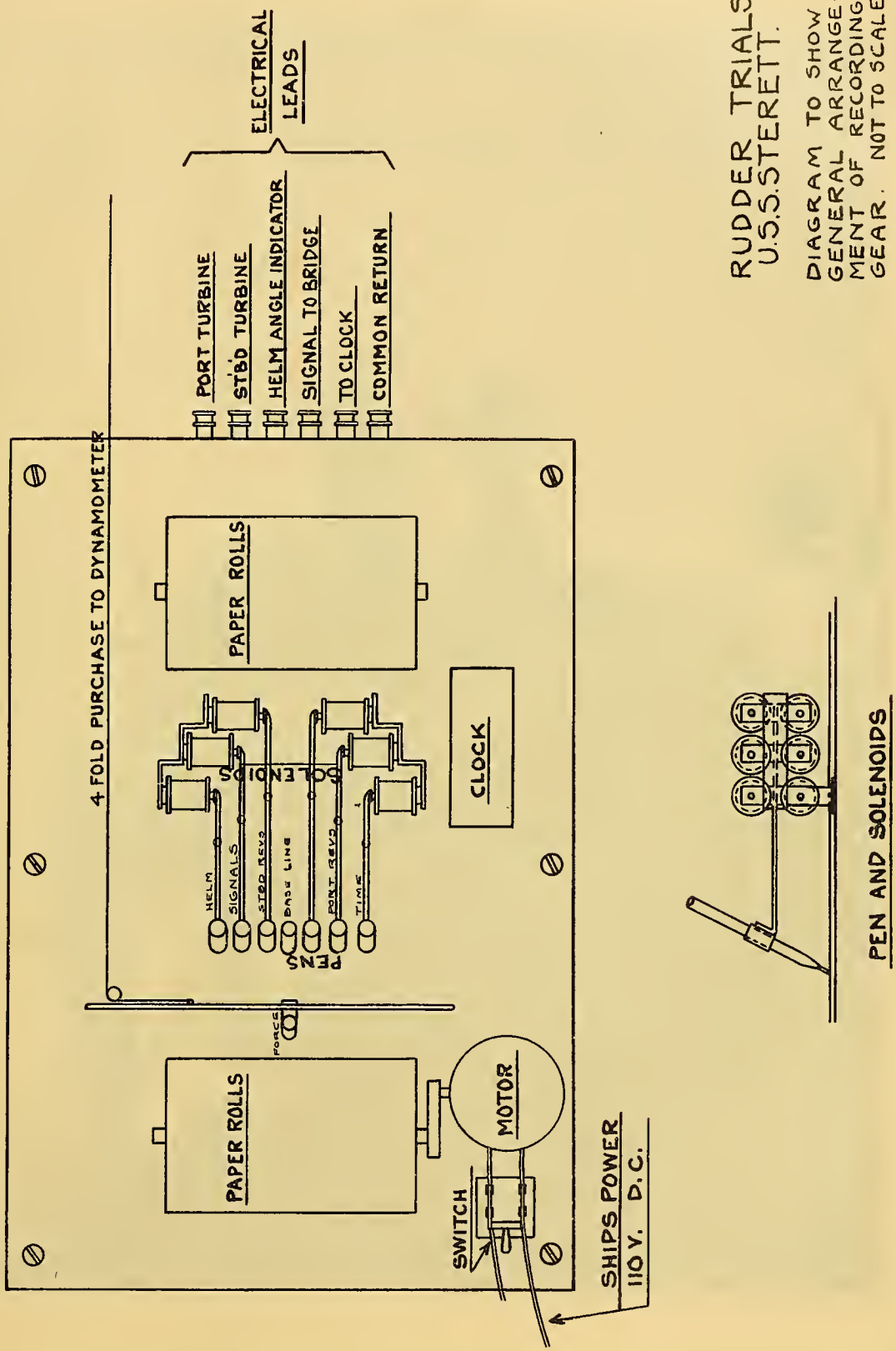
To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

FIGURE 3



To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

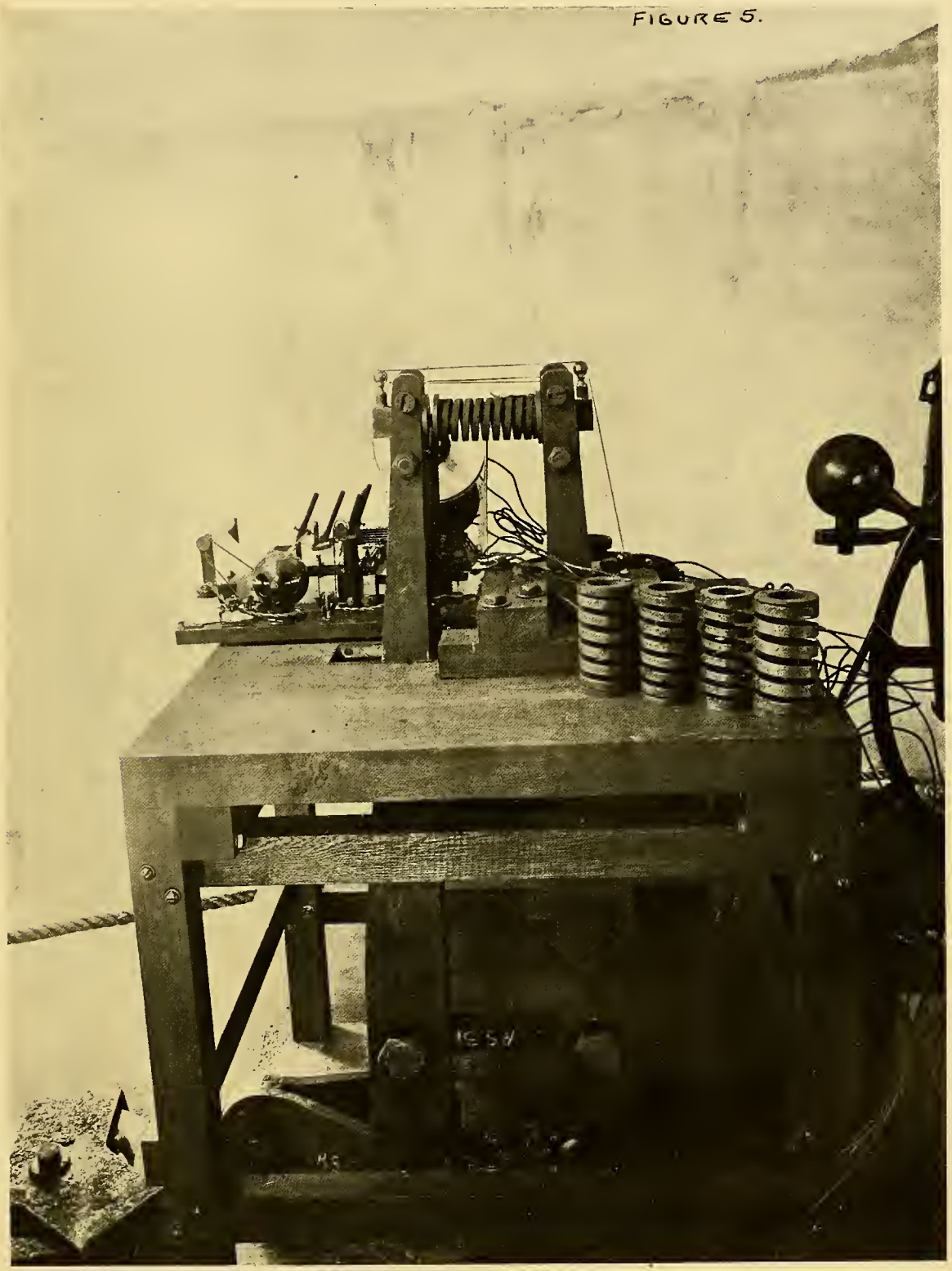
FIGURE 4.



RUDDER TRIALS
U.S.S.STERETT.

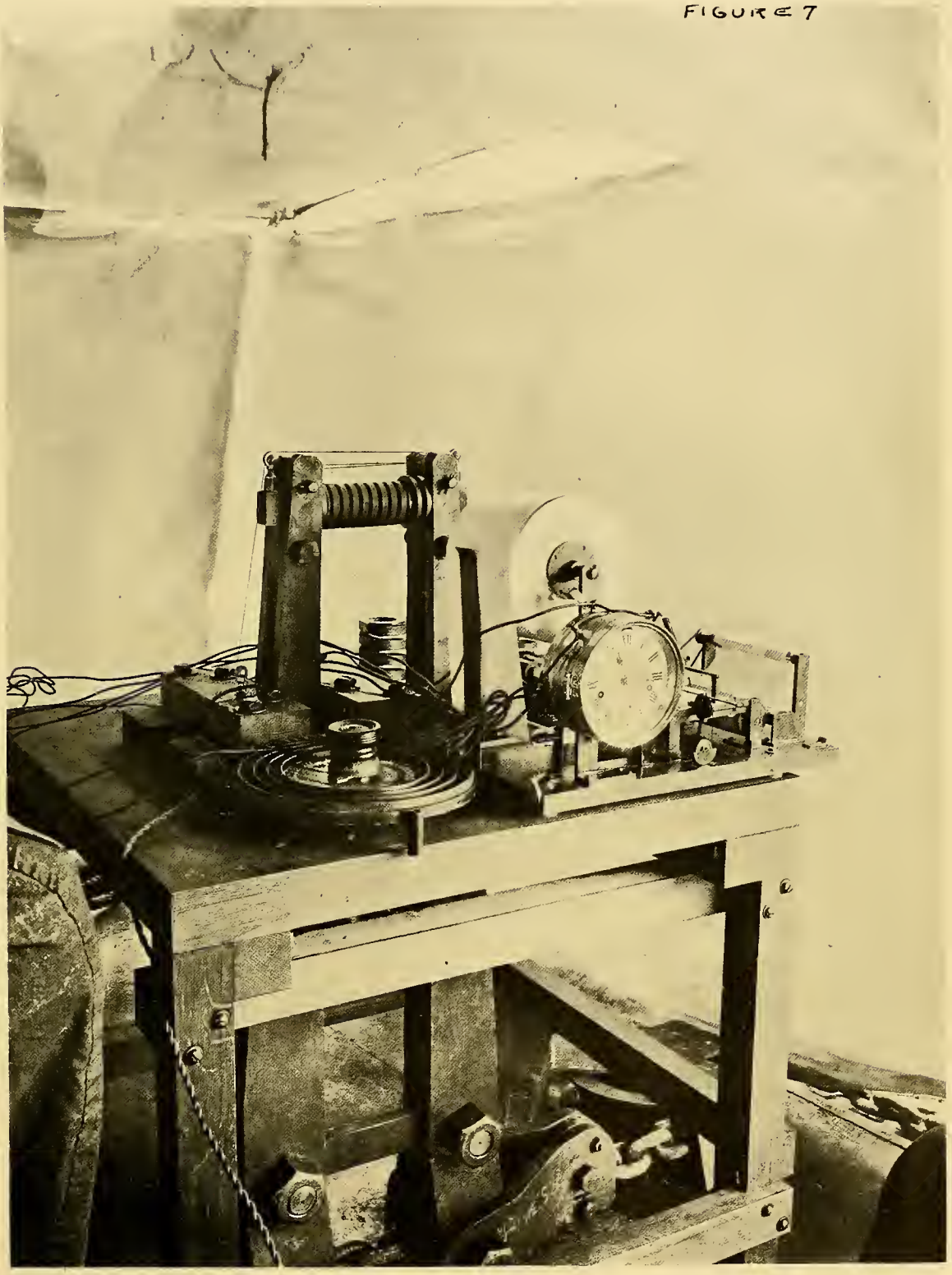
DIAGRAM TO SHOW GENERAL ARRANGEMENT OF RECORDING GEAR. NOT TO SCALE.

To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

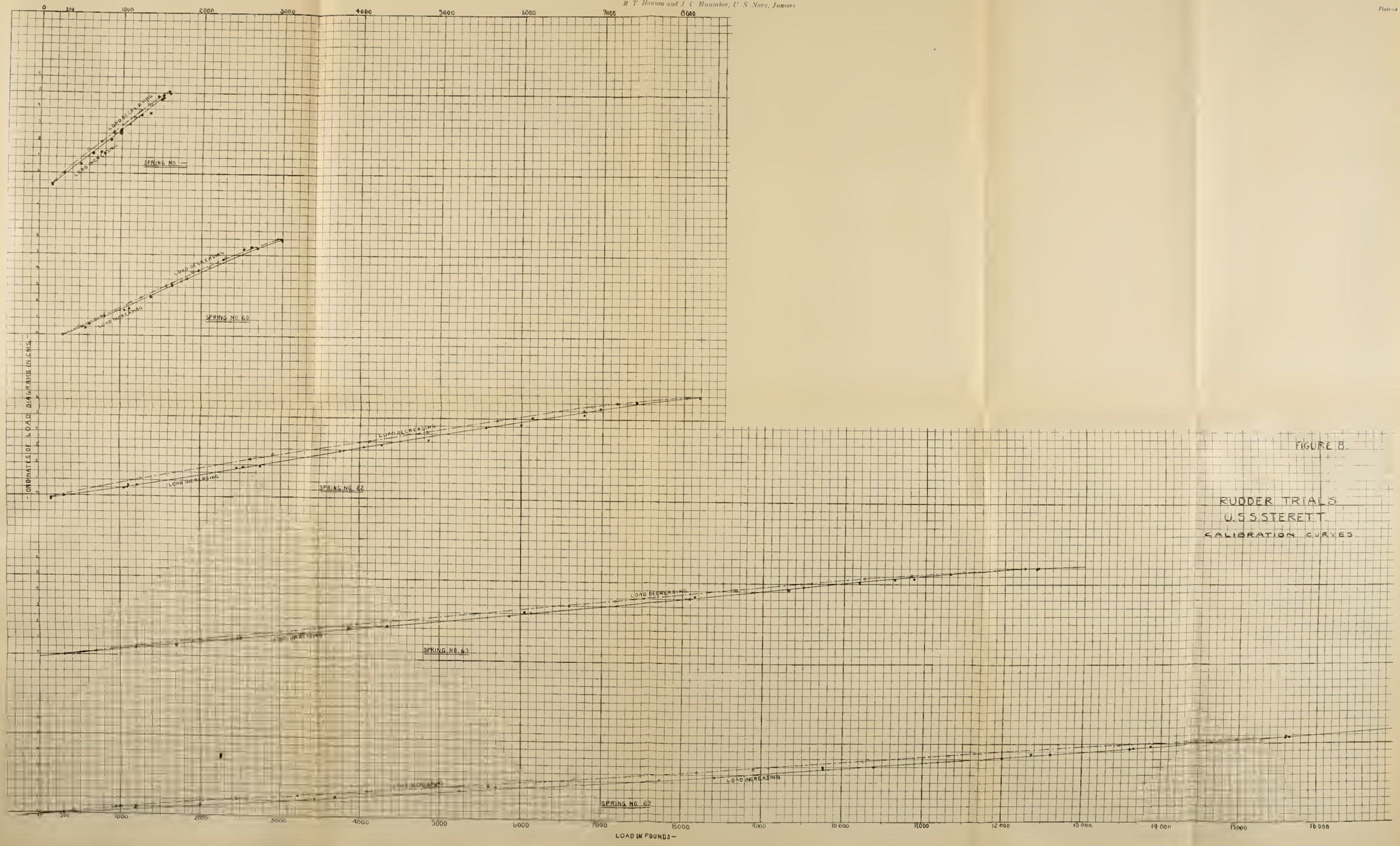


To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

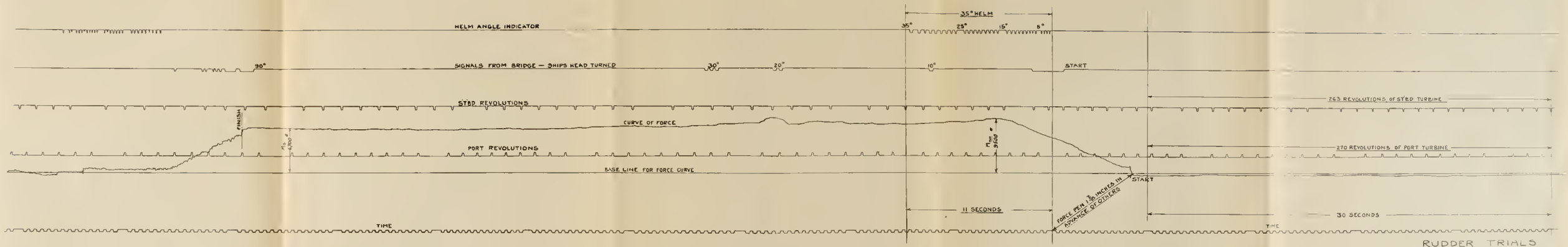


To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors



To illustrate paper on "Rudder Trials, U S S Sterett," by Assistant Naval Constructors R T Hanson and J C Hunsaker, U S Navy, Juniors

FIGURE 4

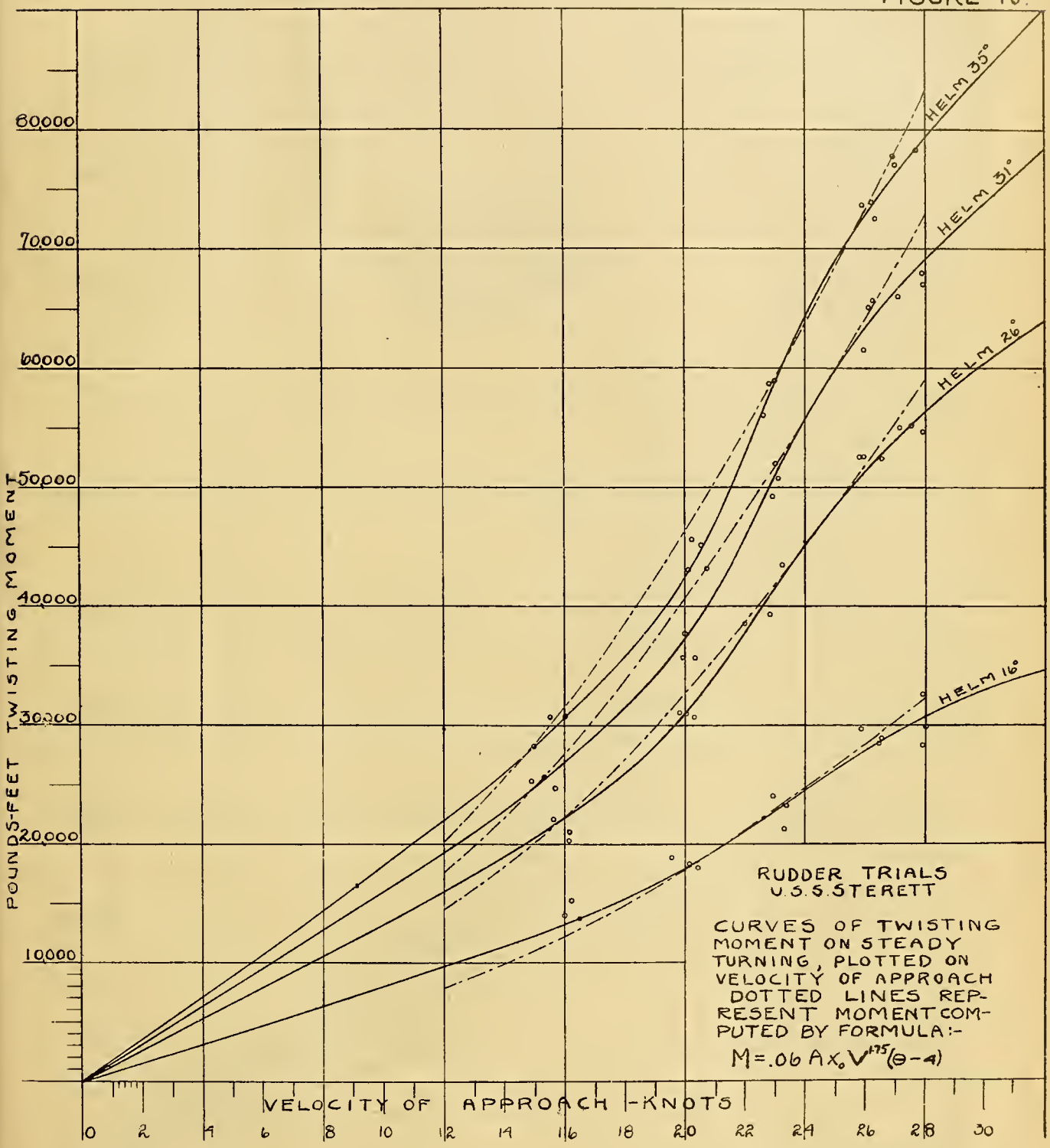


RUDDER TRIALS
USS STERETT

TRACING OF AN ACTUAL RECORD MADE, WHILE TURNING, BY RECORDING DYNAMOMETER. FULL SIZE

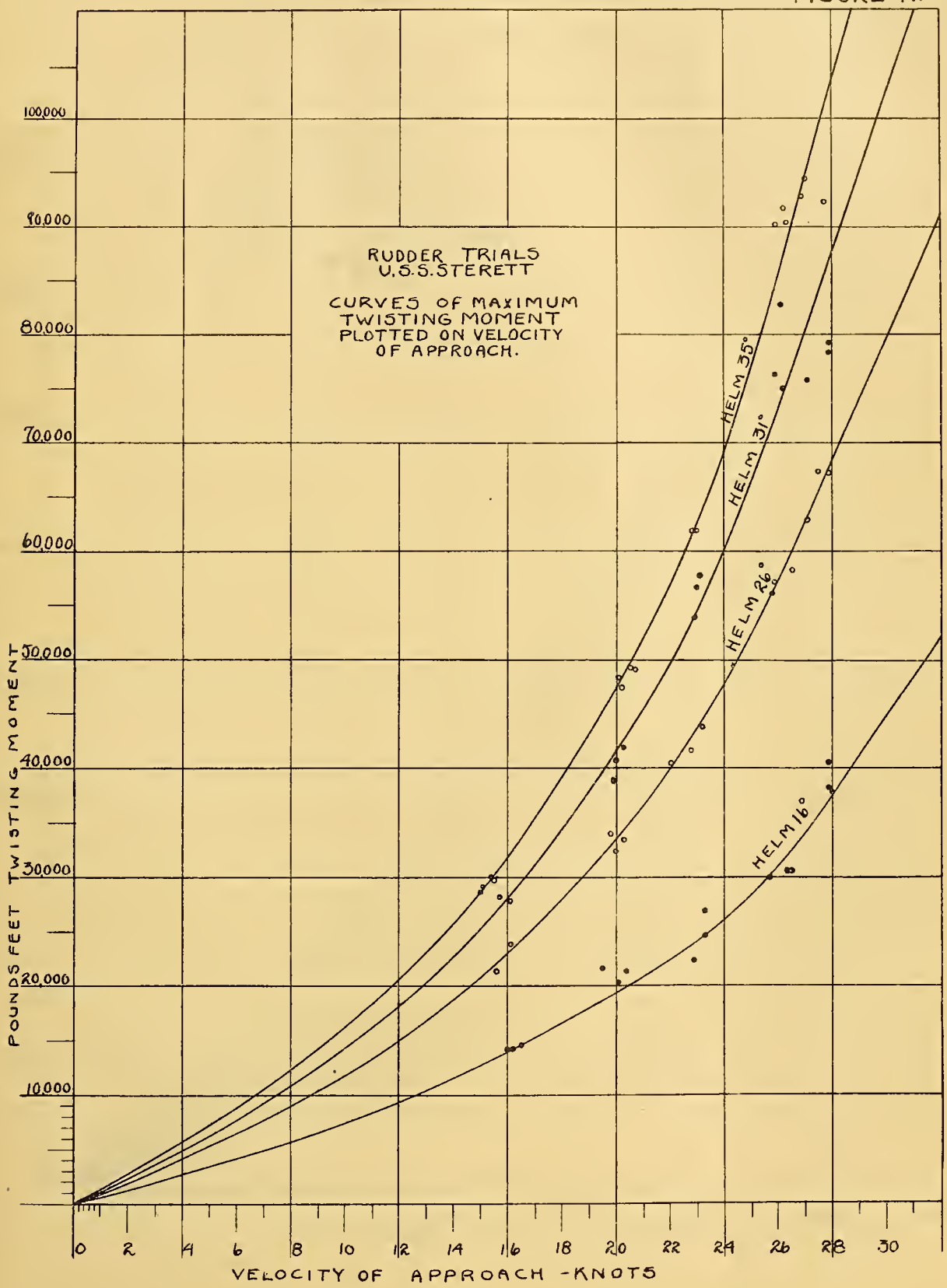
To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

FIGURE 10.



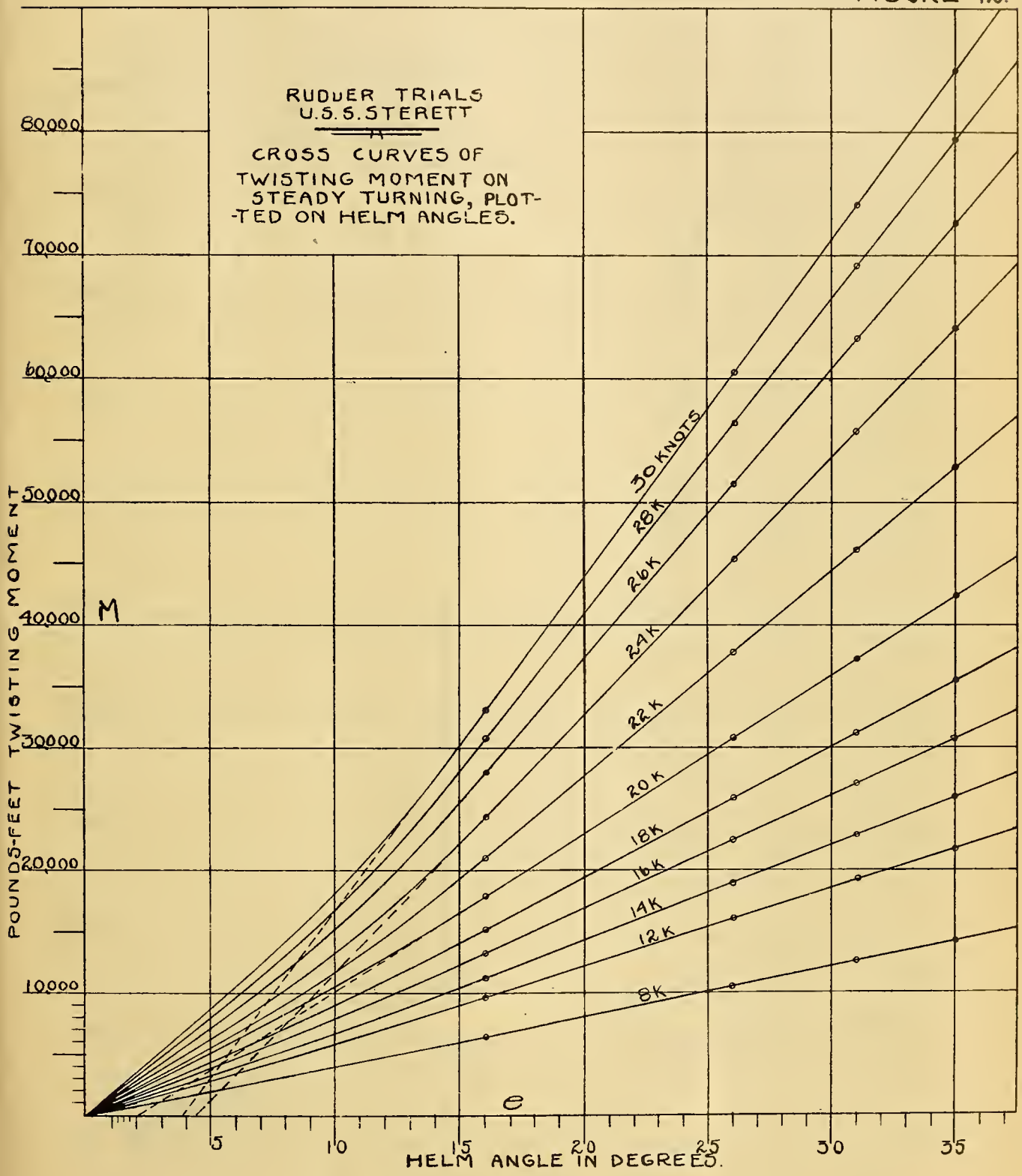
To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

FIGURE 11.



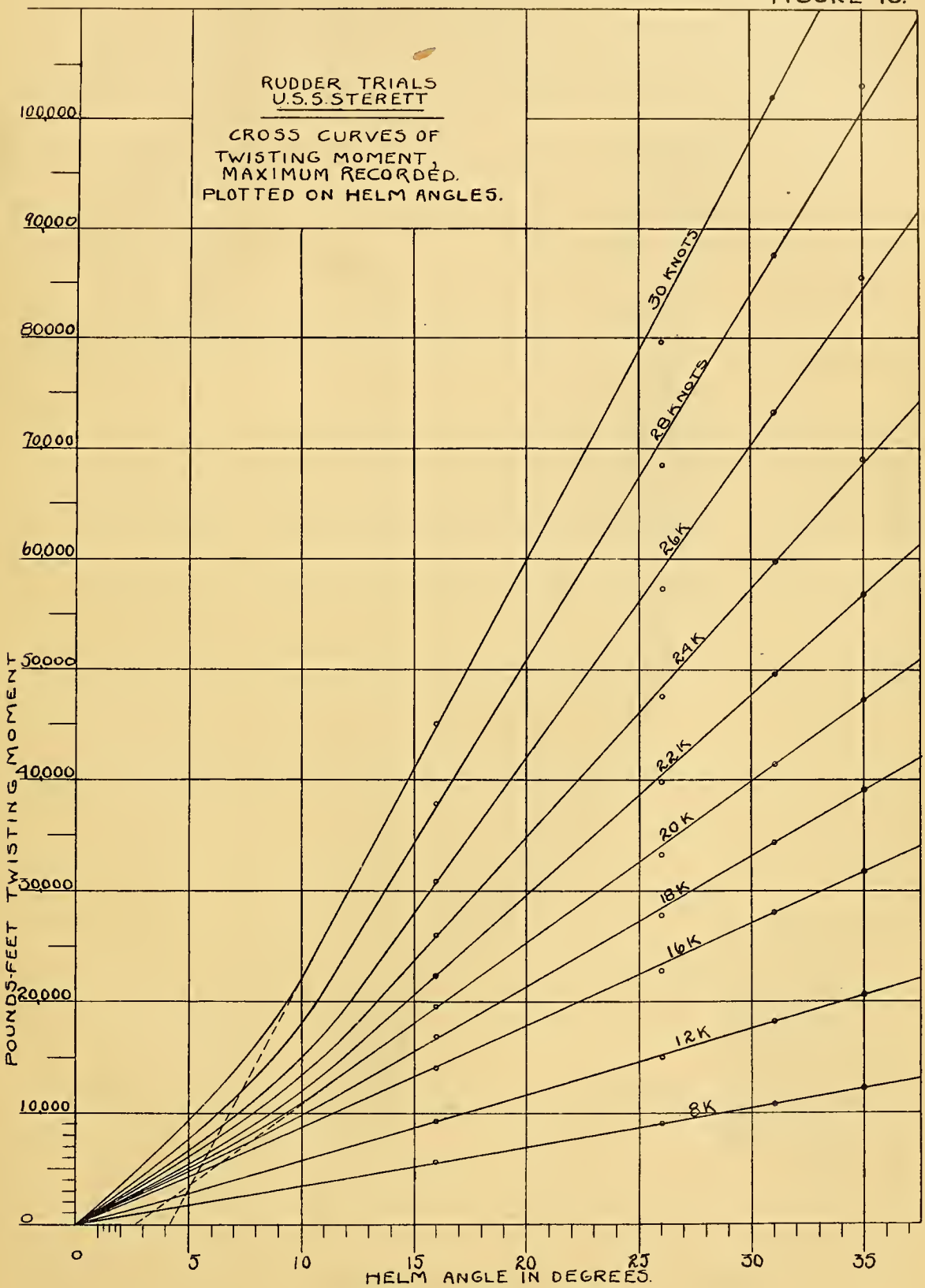
To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

FIGURE 12.



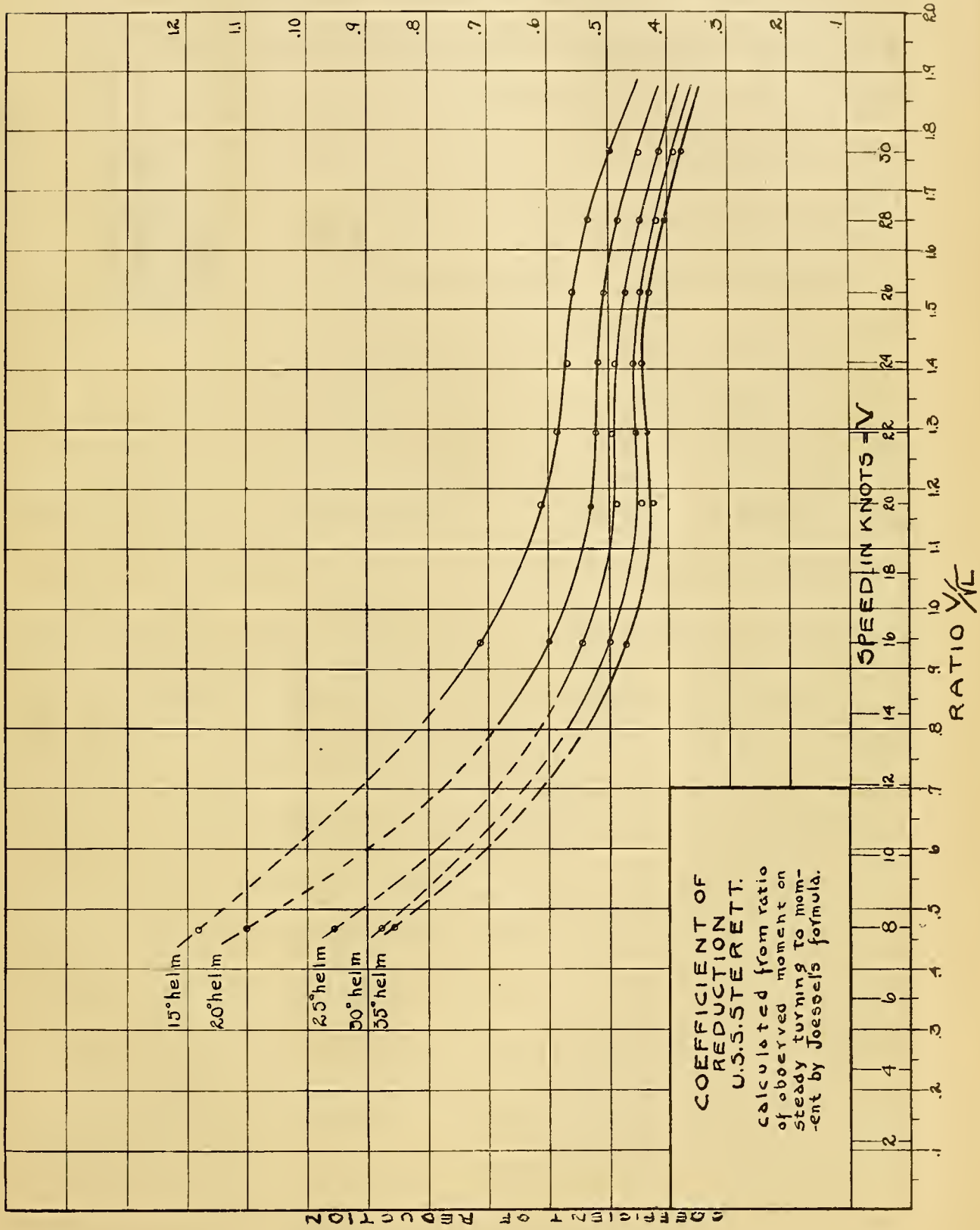
To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

FIGURE 13.

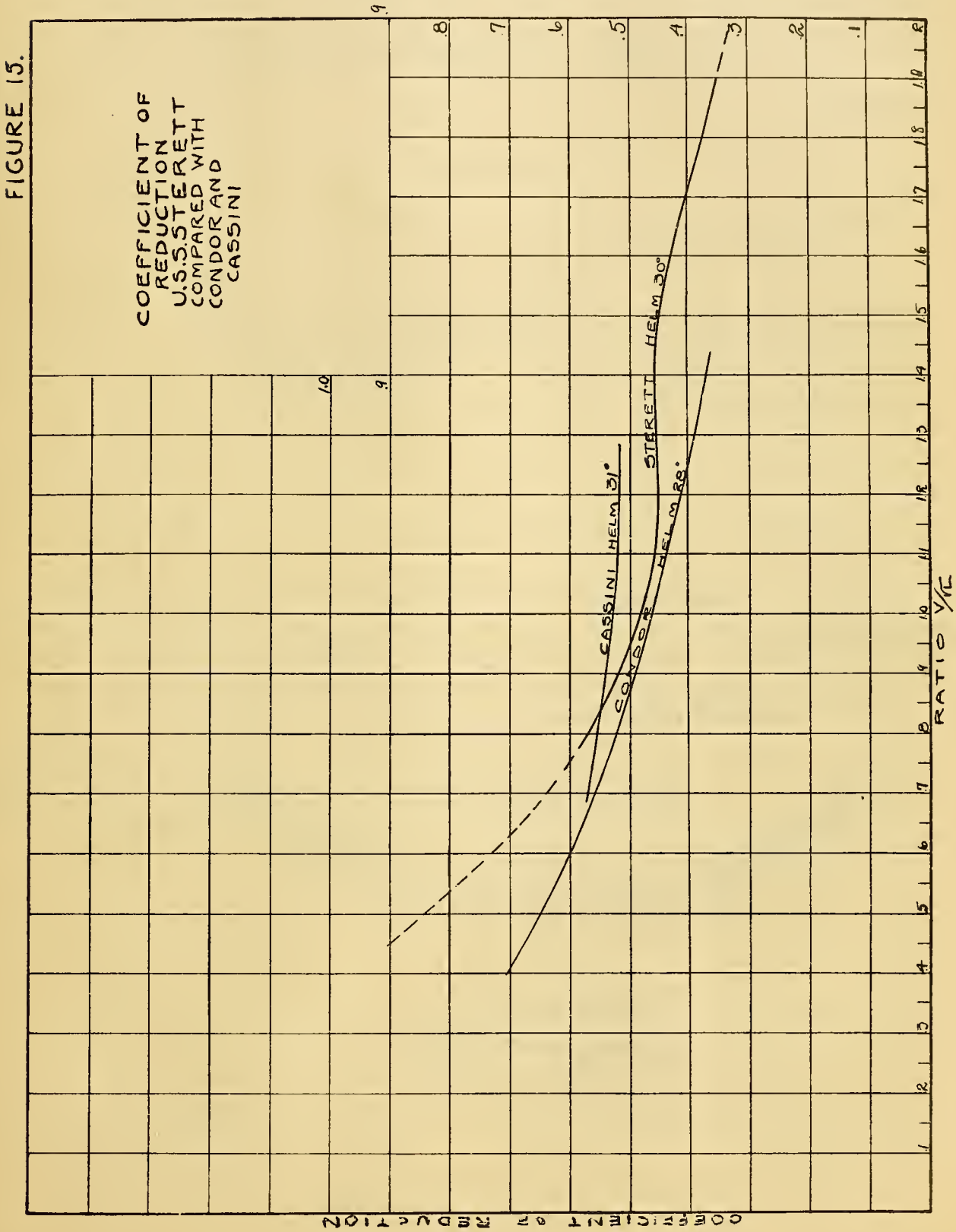


To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

FIGURE 14.

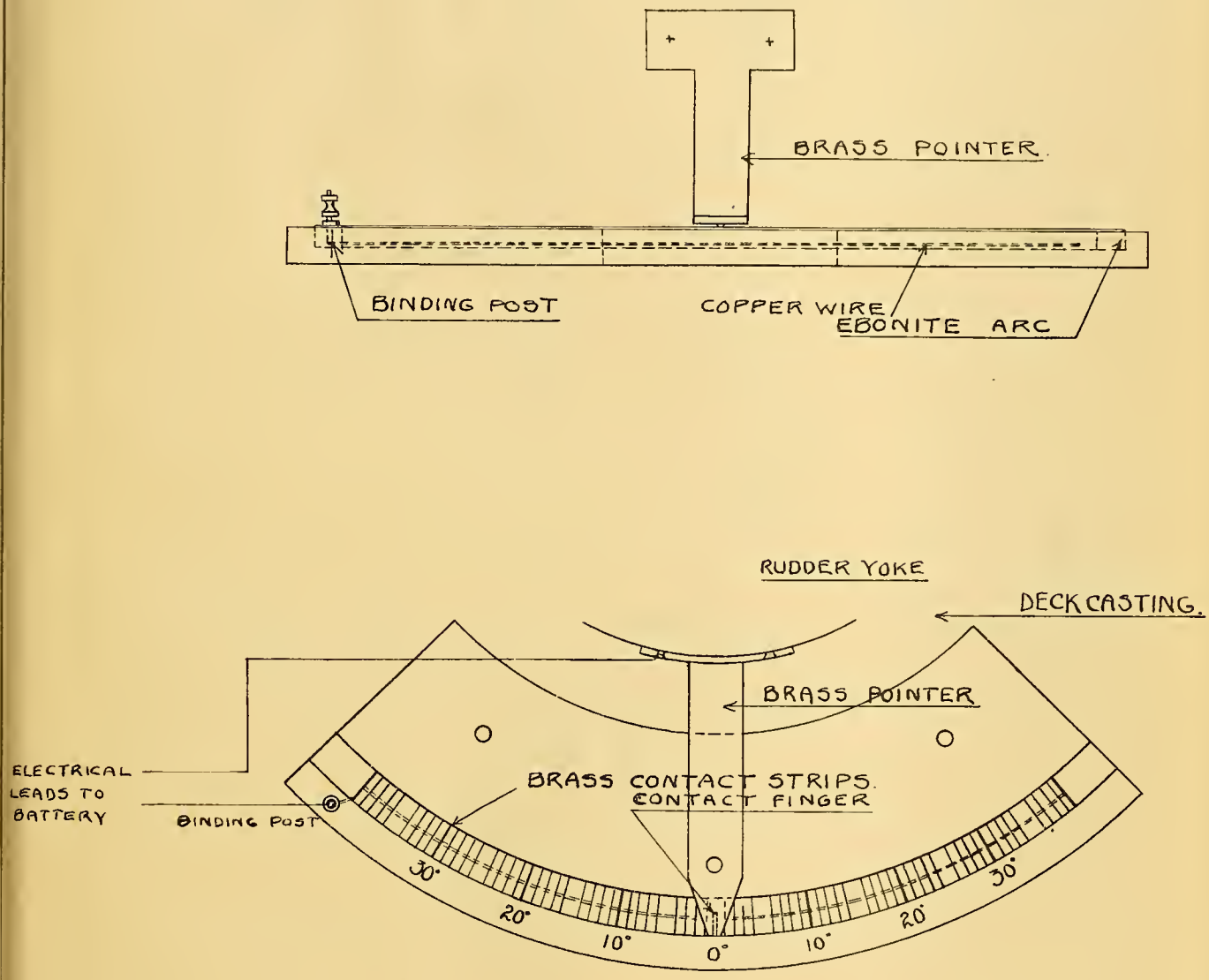


To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.



To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

FIGURE 16.

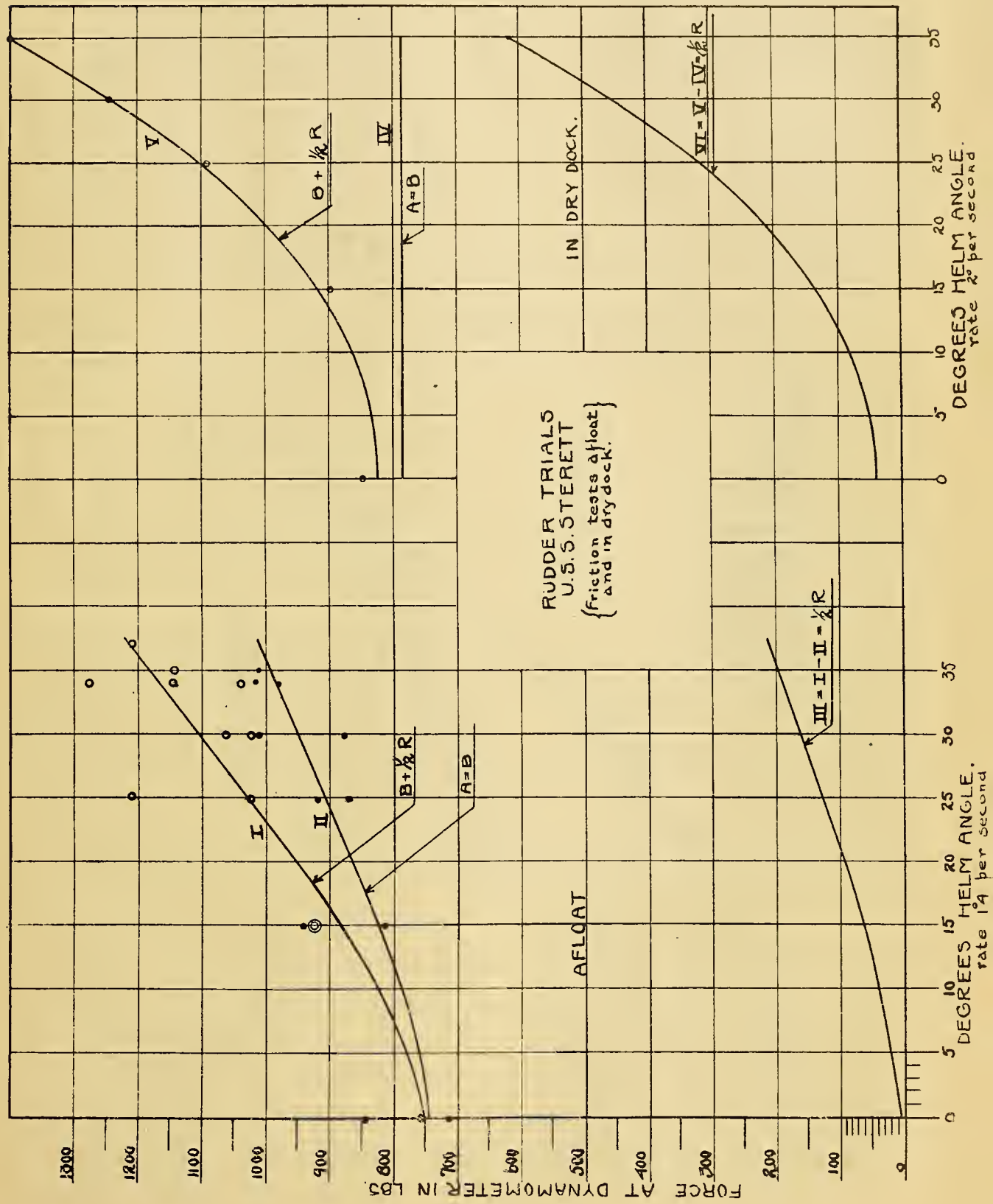


RUDDER TRIALS
U.S.S. STERETT

ELECTRICAL HELM
ANGLE INDICATOR
SCALE 3"=1 FT.

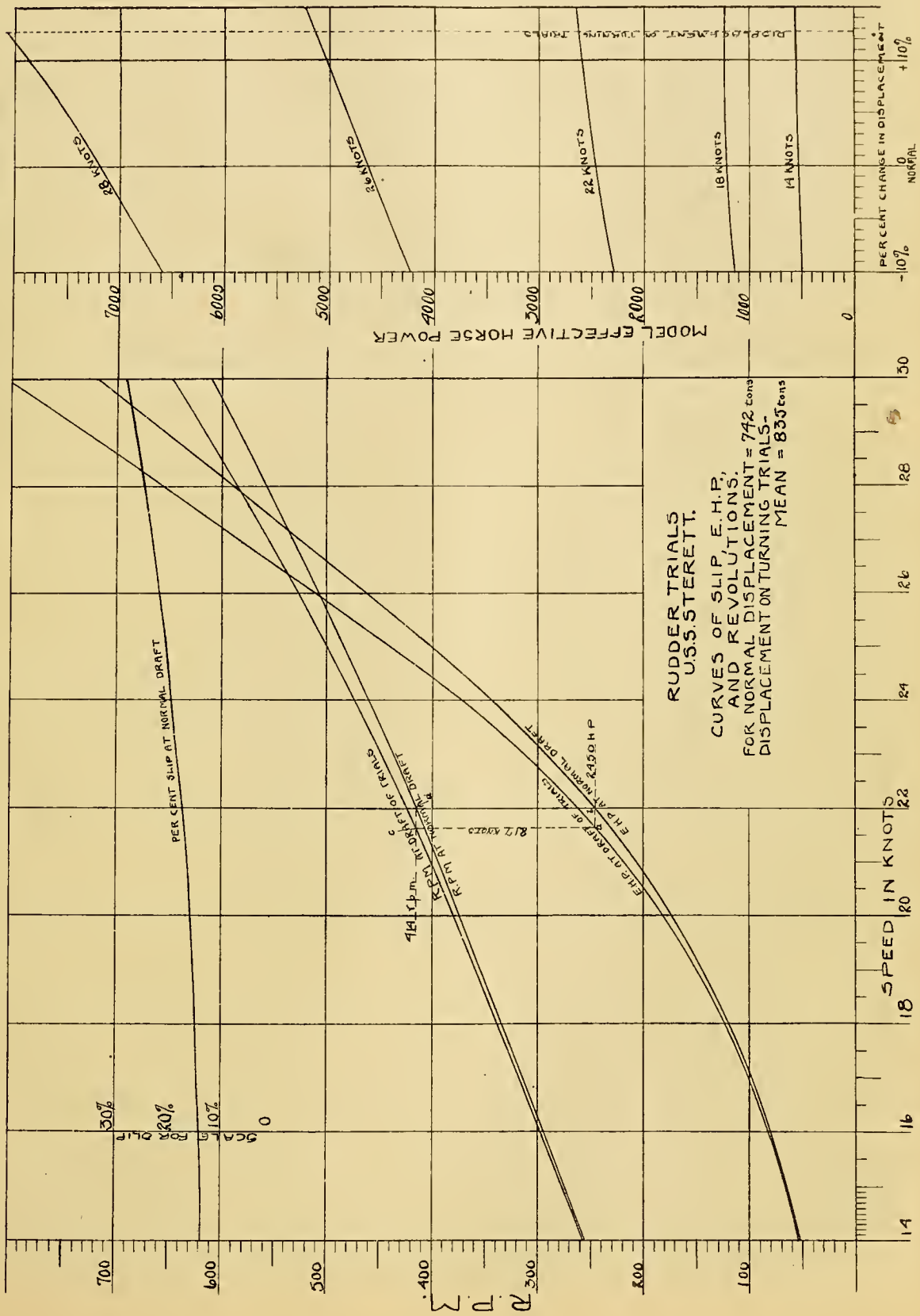
To illustrate paper on 'Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

FIGURE 17.

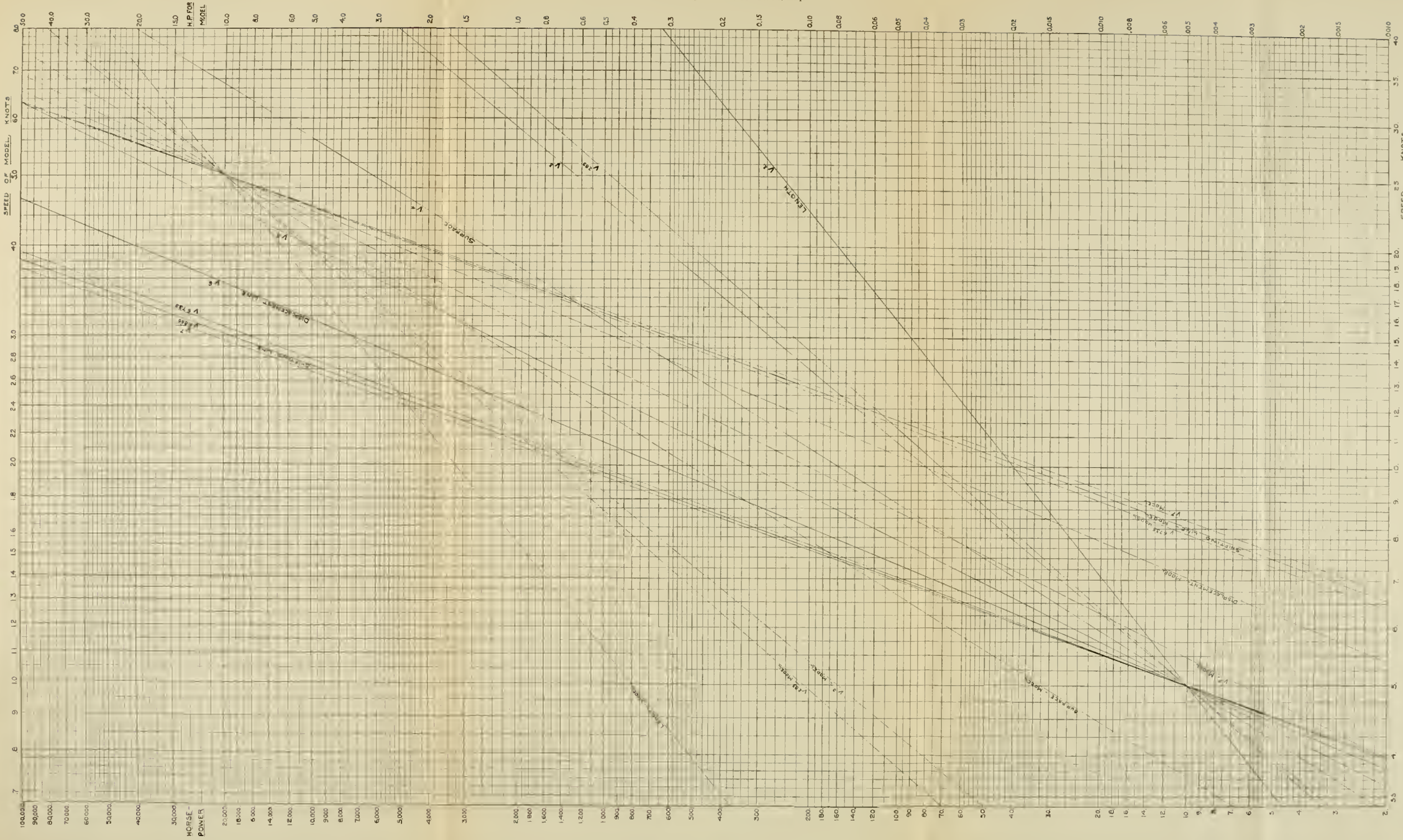


To illustrate paper on "Rudder Trials, U. S. S. Sterett," by Assistant Naval Constructors R. T. Hanson and J. C. Hunsaker, U. S. Navy, Juniors.

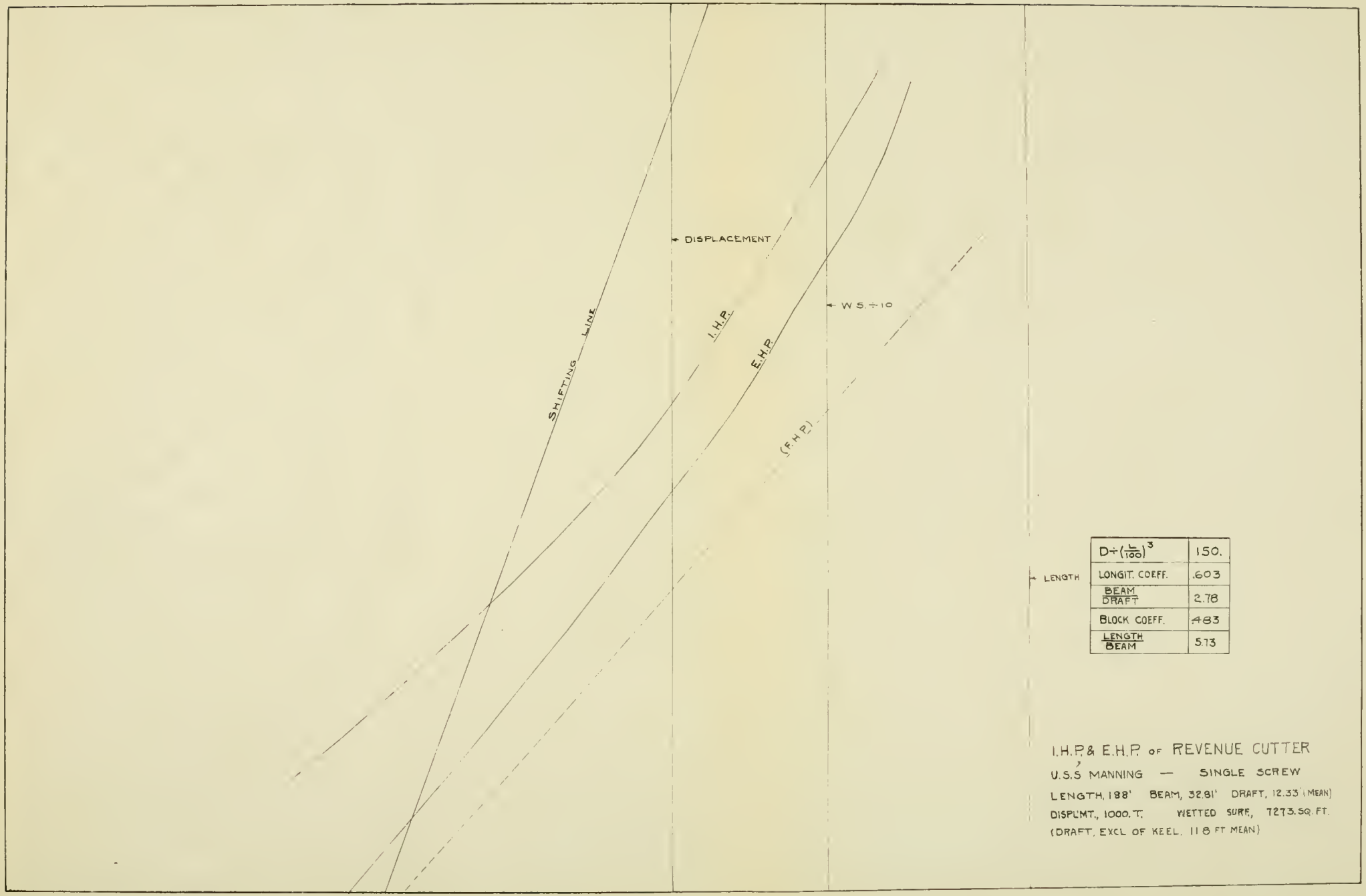
FIGURE 18.



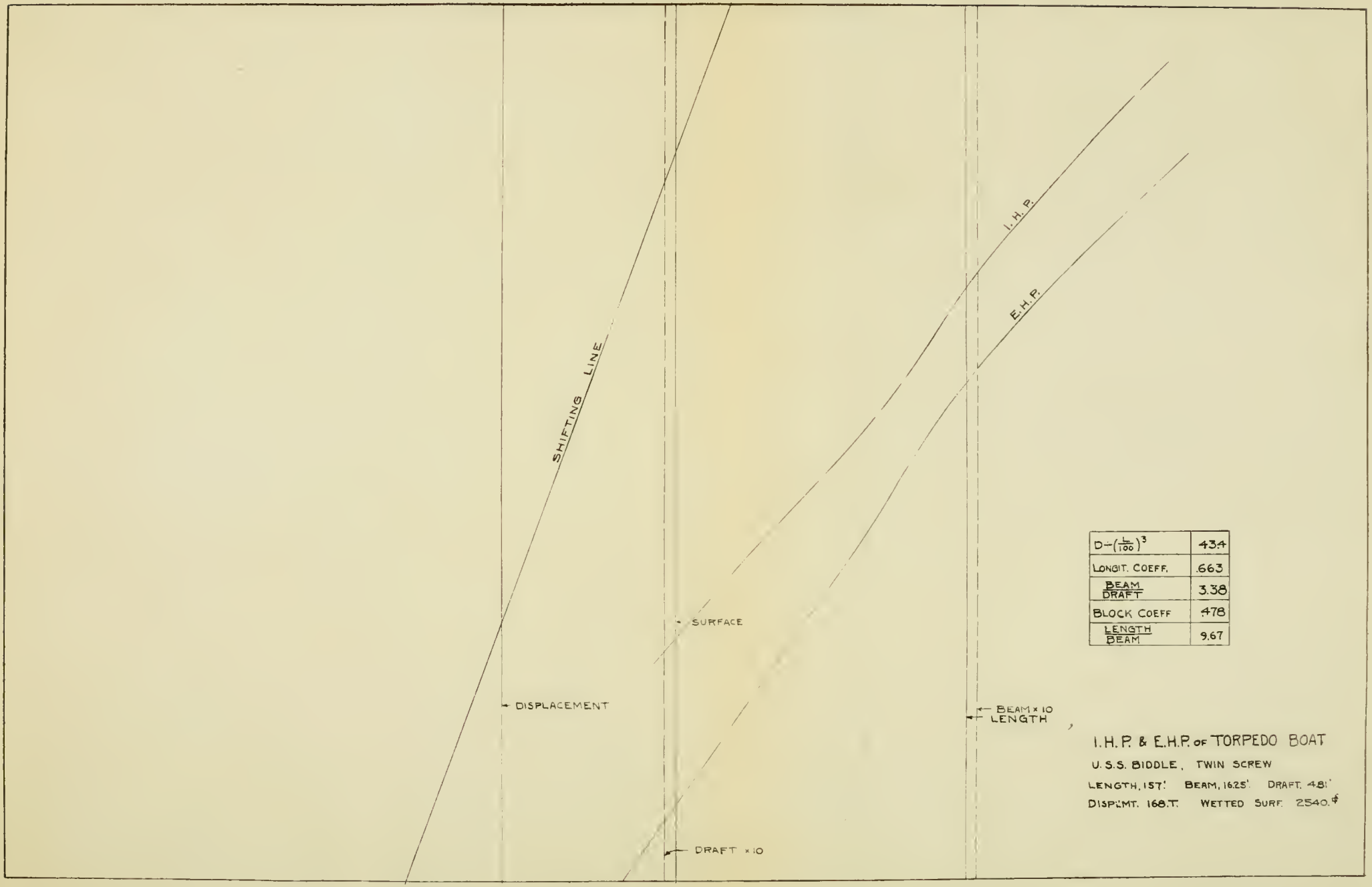
To illustrate paper on "Logarithmic Speed-Power Diagram," by Thomas M. Gunn, Esq.



To illustrate paper on "Logarithmic Speed-Power Diagram," by Thomas M. Gunn, Esq.

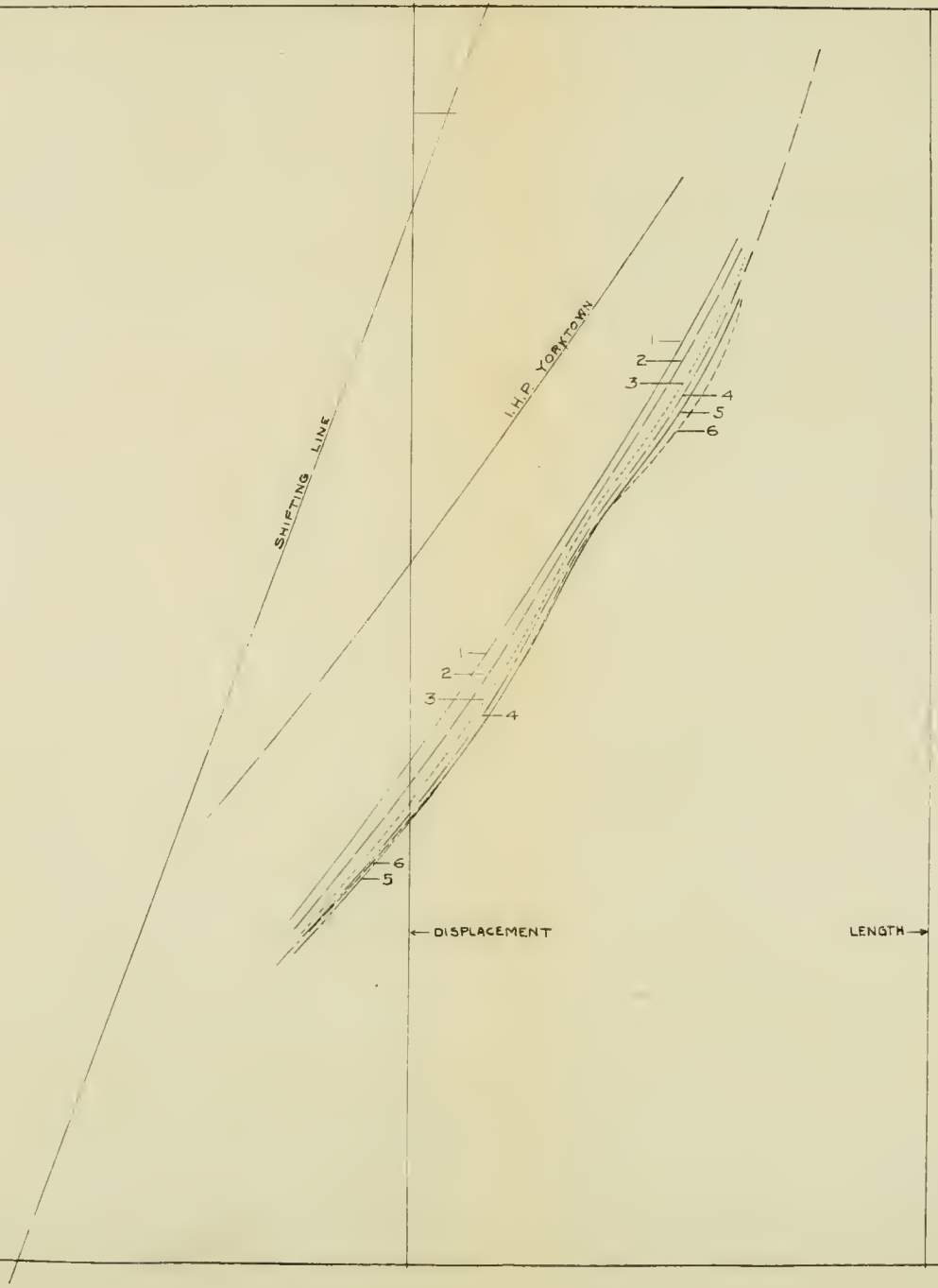


To illustrate paper on "Logarithmic Speed-Power Diagram," by Thomas M. Gunn, Esq.



To illustrate paper on "Logarithmic
by Thomas M. Gu

To illustrate paper on "Logarithmic Speed-Power Diagram," by Thomas M. Gunn, Esq.

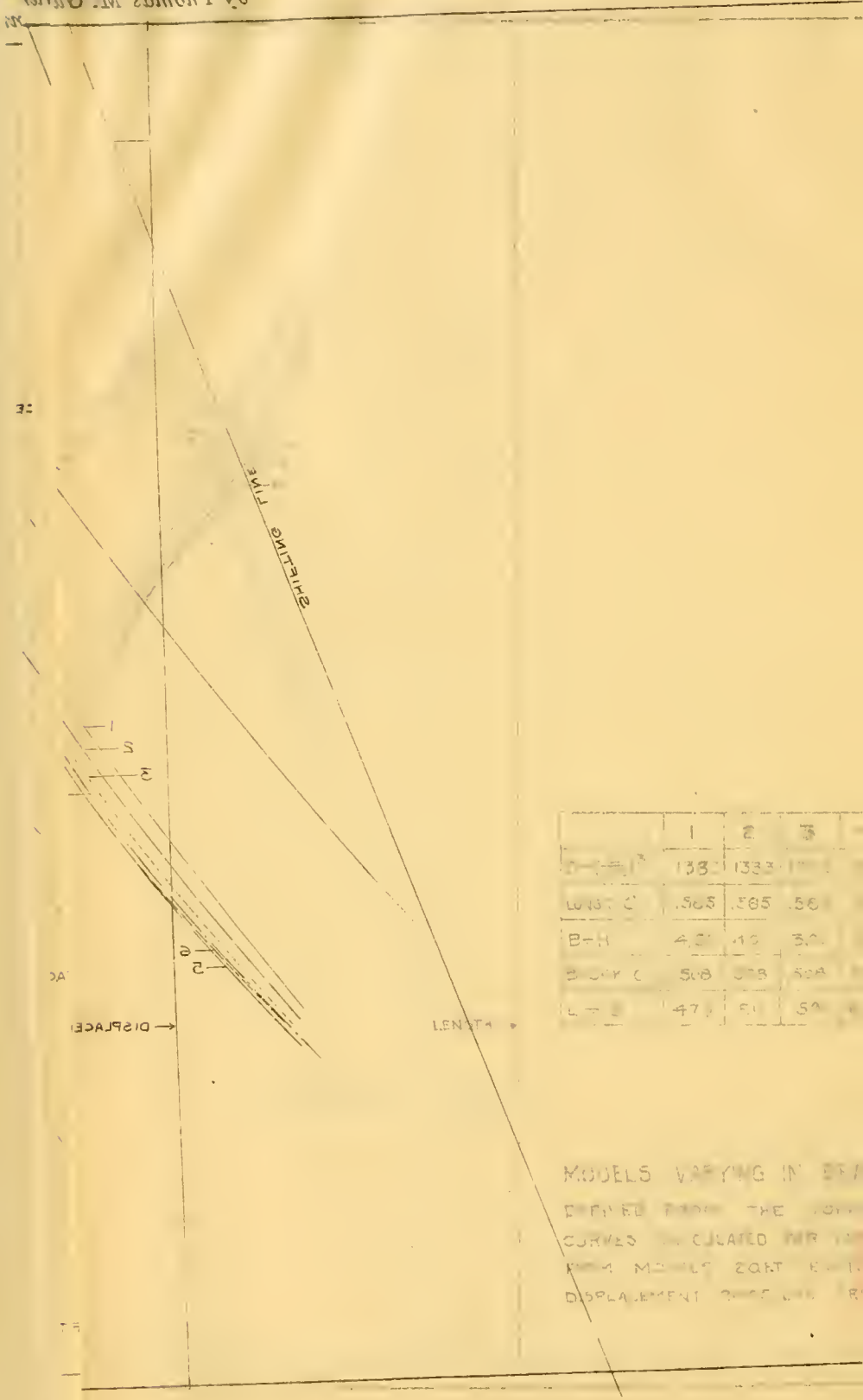


	1	2	3	4	5	6
$D \div (\frac{L}{100})^3$	138.3	138.3	138.3	138.3	138.3	138.3
LONGIT. C.	.585	.585	.585	.585	.585	.585
B÷H.	4.56	4.01	3.02	2.57	2.16	1.44
BLOCK C.	.508	.508	.508	.508	.508	.508
L ÷ B	4.79	5.11	5.90	6.35	6.97	8.57

MODELS VARYING IN BEAM & DEPTH
DERIVED FROM THE YORKTOWN.
CURVES CALCULATED FOR 100 FT. LENGTH
FROM MODELS 20 FT. LENGTH.
DISPLACEMENT, 2405. LBS. FRESH WATER.

al Architects and Marine Engineers, Vol. 20, 1912.

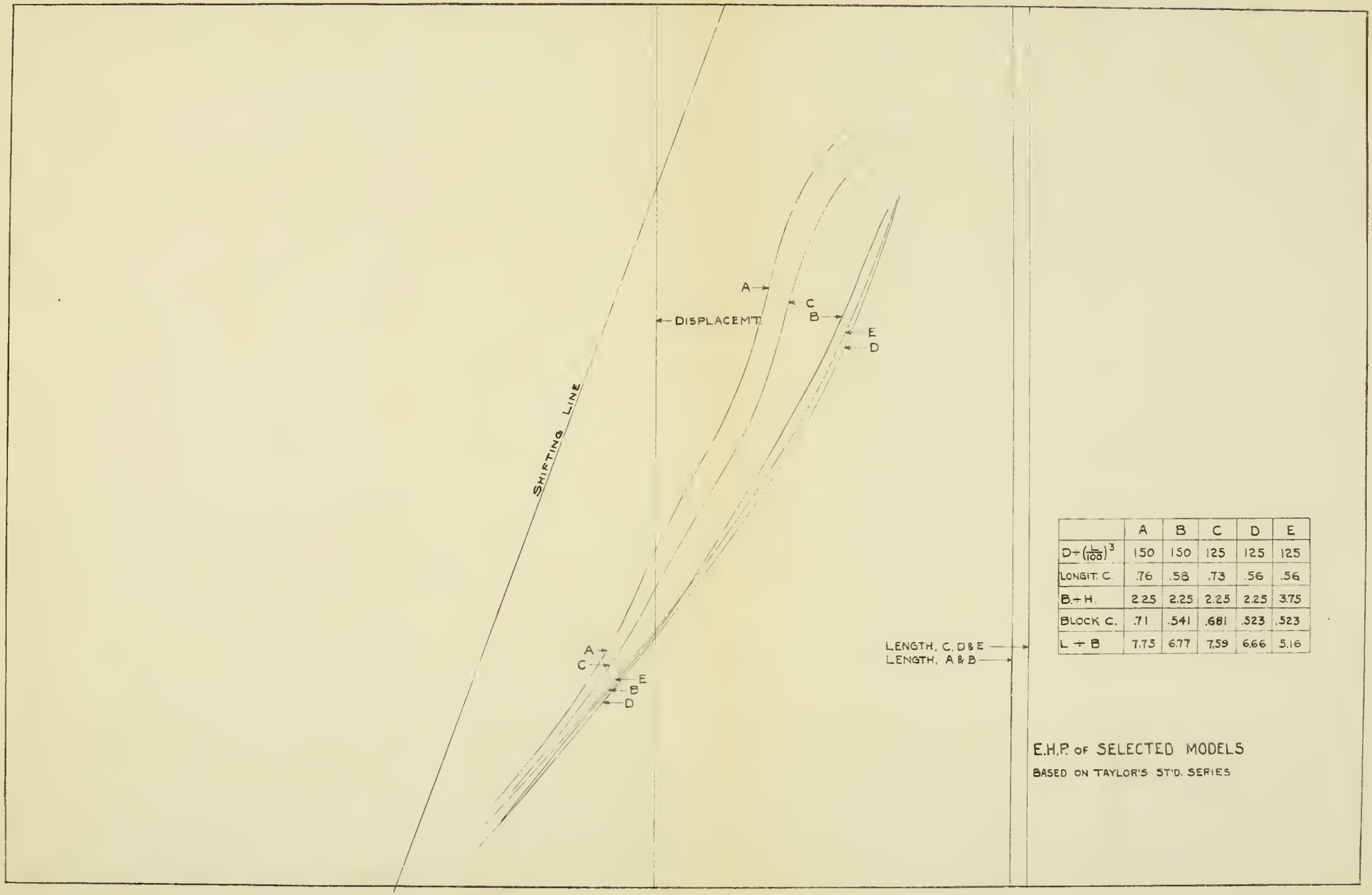
To illustrate paper on "Logarithmic
by Thomas M. Guin



	1	2	3
[illegible]	1383	1333	[illegible]
LONG. C	.565	.565	.56[illegible]
B-H	4.[illegible]	[illegible]	3.[illegible]
B[illegible] C	.508	[illegible]	.508
L-[illegible]	47[illegible]	[illegible]	.5[illegible]

MODELS VARYING IN [illegible]
DEFINED FROM THE [illegible]
CURVES [illegible] CULATED [illegible]
FROM MODELS [illegible]
DISPLACEMENT [illegible]

To illustrate paper on "Logarithmic Speed-Power Diagram," by Thomas M. Gunn, Esq.

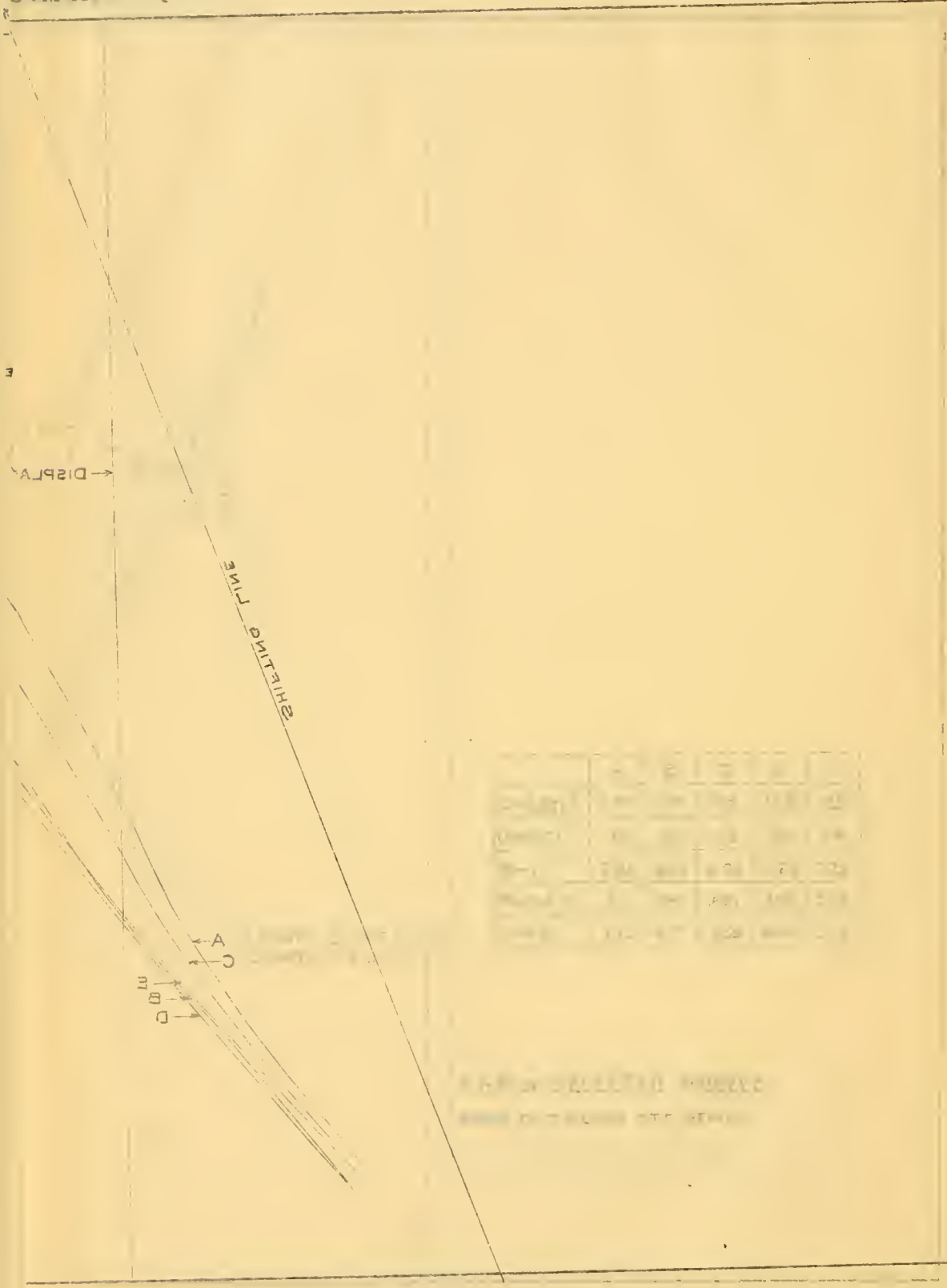


	A	B	C	D	E
$D \div \left(\frac{L}{100}\right)^3$	150	150	125	125	125
LONGIT. C.	.76	.58	.73	.56	.56
B. ÷ H.	2.25	2.25	2.25	2.25	3.75
BLOCK C.	.71	.541	.681	.523	.523
L ÷ B	7.75	6.77	7.59	6.66	5.16

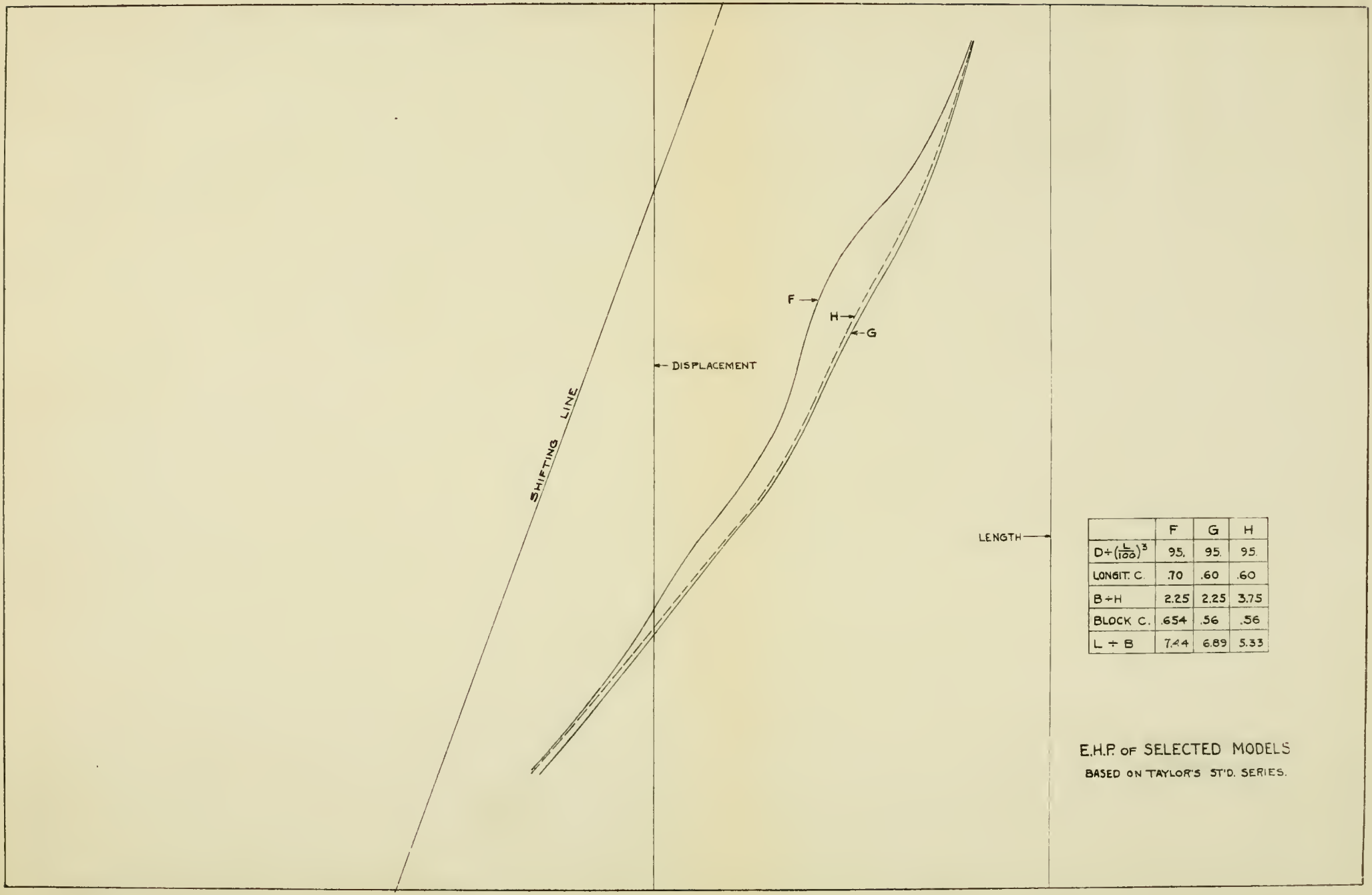
E.H.P. OF SELECTED MODELS

BASED ON TAYLOR'S ST'D. SERIES

To illustrate paper on "Logarithm
by Thomas M. C



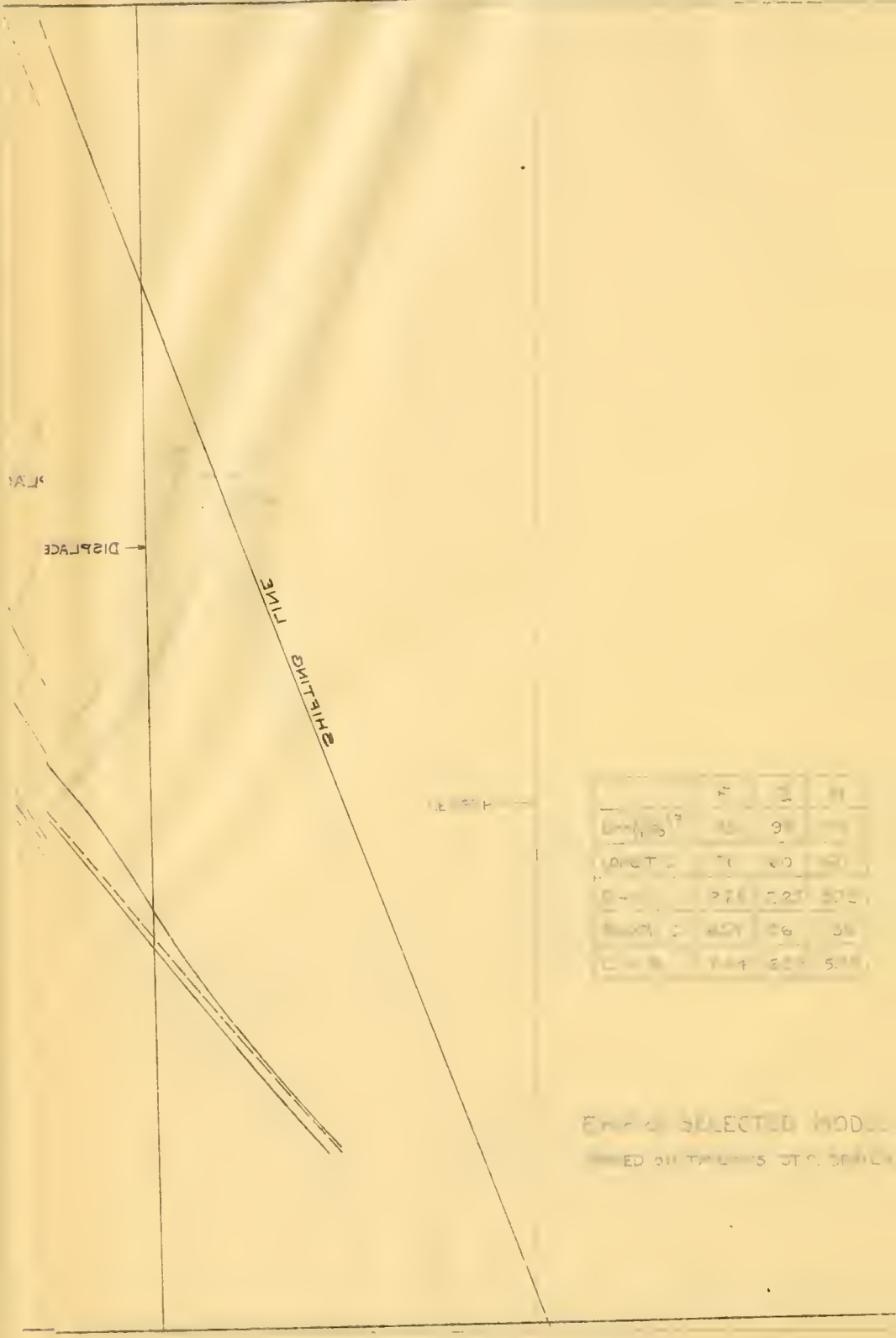
To illustrate paper on "Logarithmic Speed-Power Diagram," by Thomas M. Gunn, Esq.



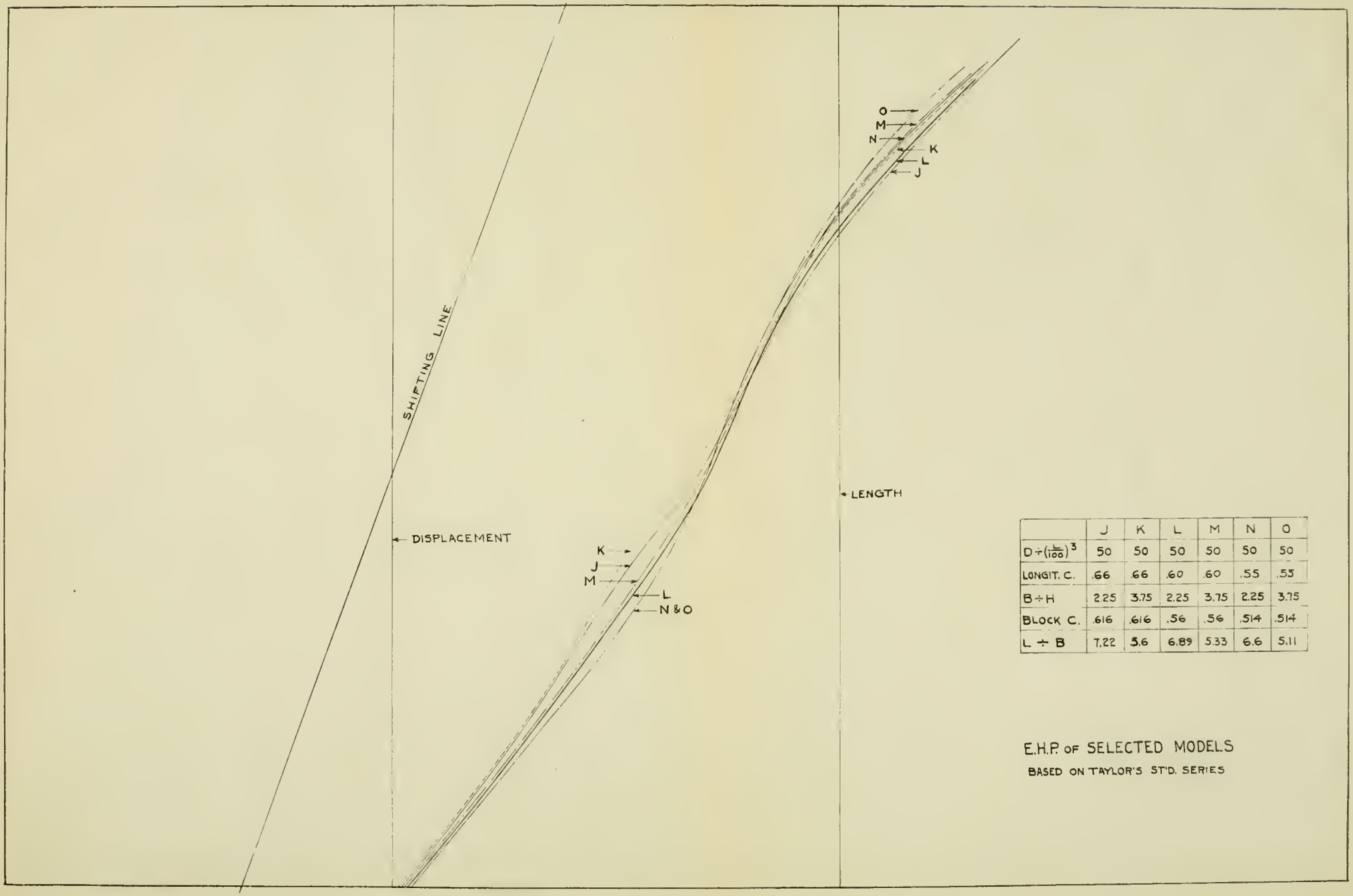
	F	G	H
$D \div (\frac{L}{100})^3$	95.	95.	95.
LONGIT. C.	.70	.60	.60
B ÷ H	2.25	2.25	3.75
BLOCK C.	.654	.56	.56
L ÷ B	7.44	6.89	5.33

E.H.P. OF SELECTED MODELS

BASED ON TAYLOR'S ST'D. SERIES.


SHIFTING LINE
DISPLACE

To illustrate paper on "Logarithmic Speed-Power Diagram," by Thomas M. Gunn, Esq.

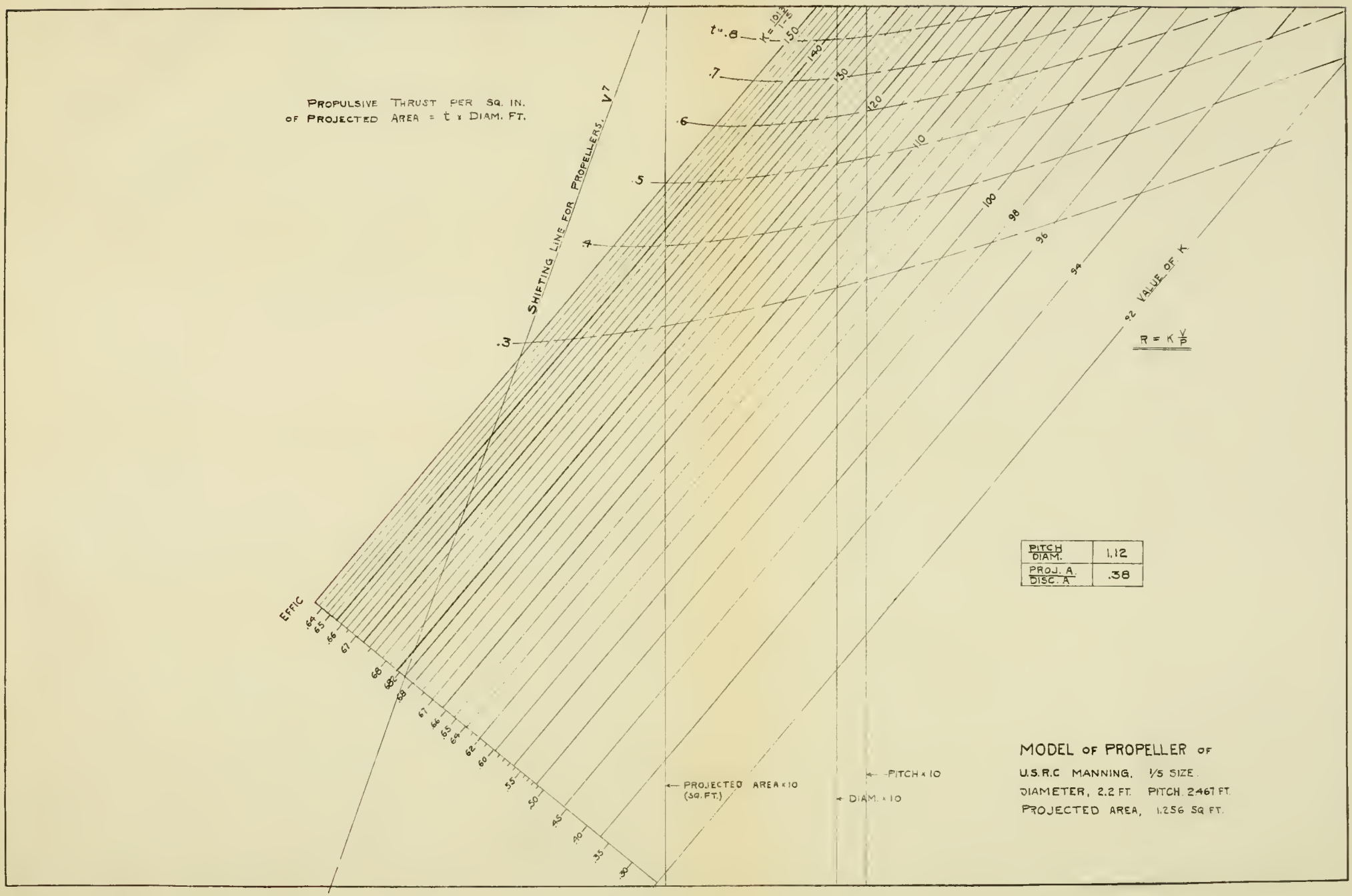


	J	K	L	M	N	O
$D \div (\frac{L}{100})^3$	50	50	50	50	50	50
LONGIT. C.	.66	.66	.60	.60	.55	.55
B ÷ H	2.25	3.75	2.25	3.75	2.25	3.75
BLOCK C.	.616	.616	.56	.56	.514	.514
L ÷ B	7.22	5.6	6.89	5.33	6.6	5.11

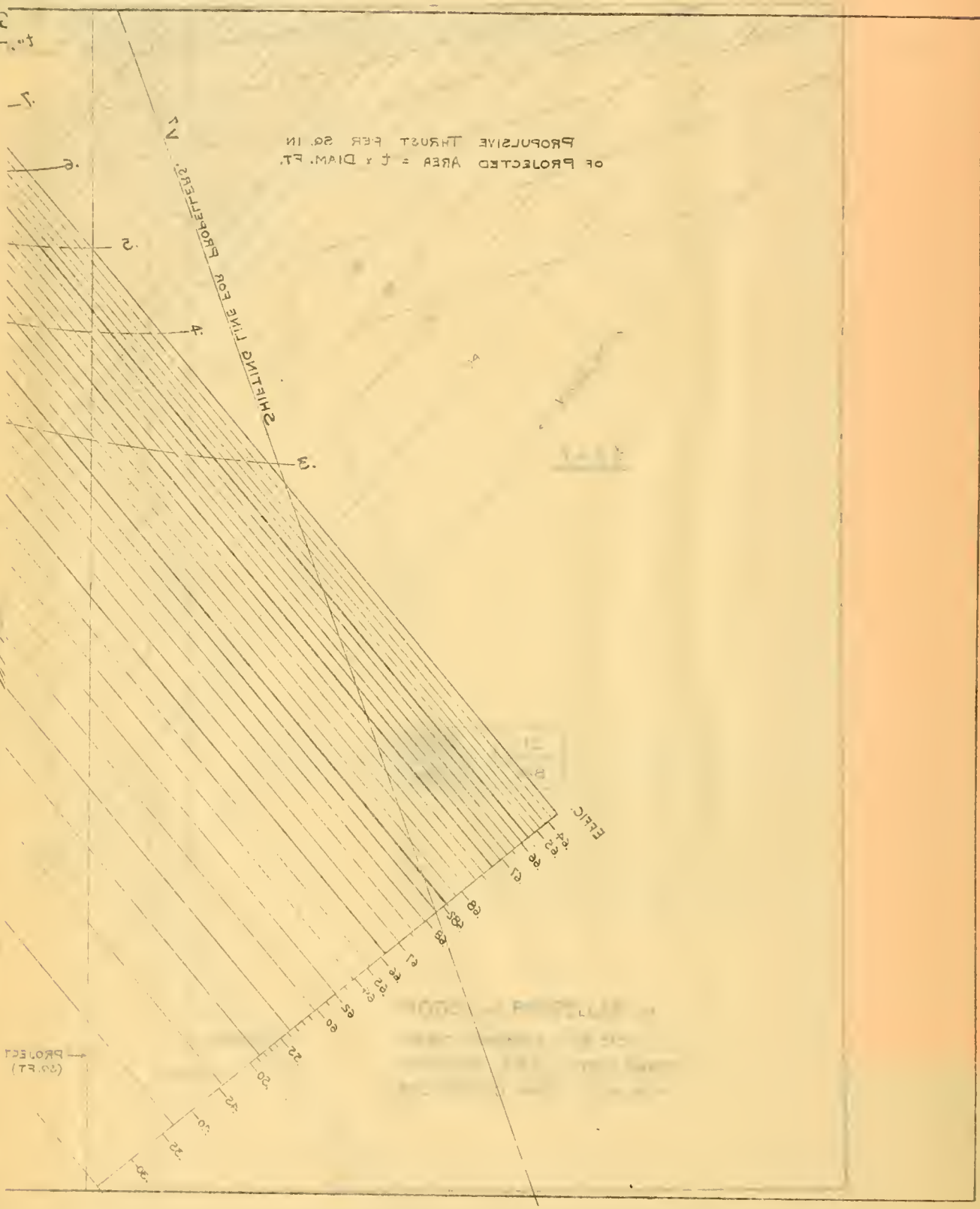
E.H.P. OF SELECTED MODELS

BASED ON TAYLOR'S ST'D. SERIES

To illustrate paper on "Logarithmic Speed-Power Diagram," by Thomas M. Gunn, Esq.



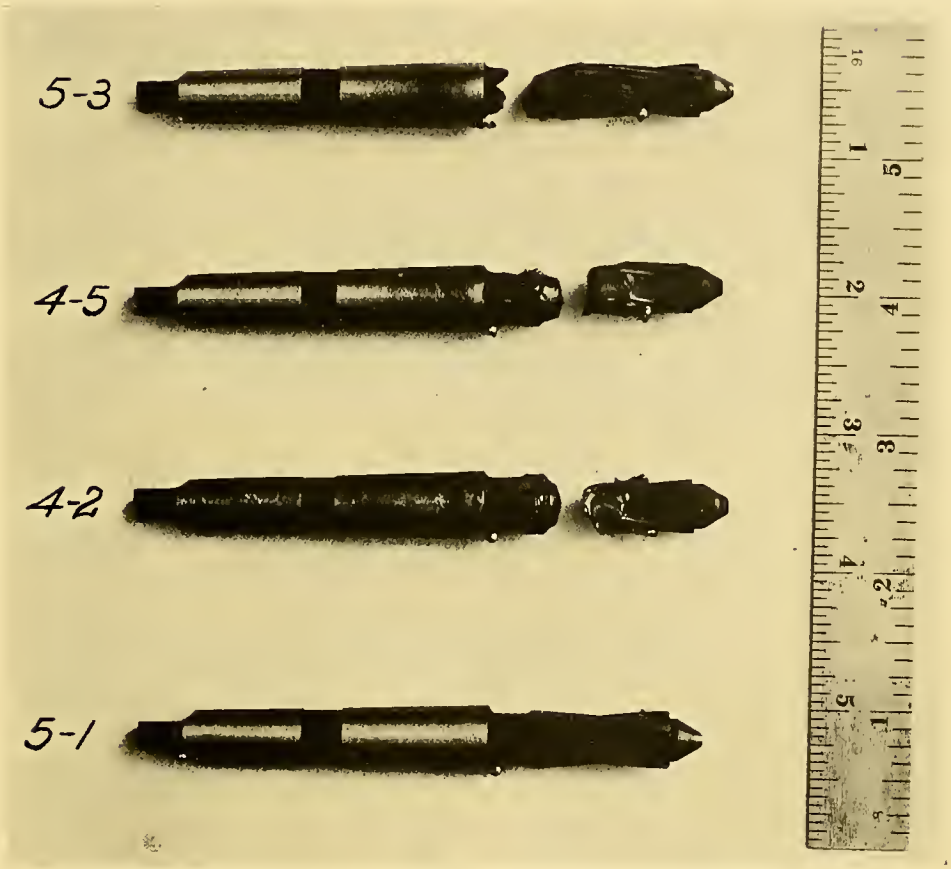
To illustrate paper on "Logarithmic S
by Thomas M. Gunn



To illustrate paper on "Tool Steel for the U. S. Navy," by Lewis Hobart Kenney, B. S., M. E., Member.

SELECTIVE TEST TOOLS. TUNGSTEN TOOL STEEL, CLASS 1, SCHEDULE 3893.

To illustrate paper on "Tool Steel for the U. S. Navy," by Lewis Hobart Kenney, B. S., M. E., Member.



SELECTIVE TEST TOOLS. CARBON TOOL STEEL, CLASS 1, SCHEDULE 4469.

To illustrate paper on "Tool Steel for the U. S. Navy," by Lewis Hobart Kenney, B. S., M. E., Member.

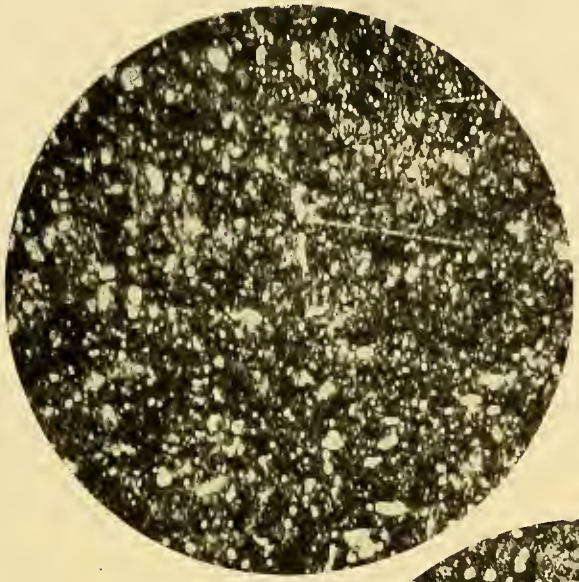


FIG. 1.

FIG. 2.

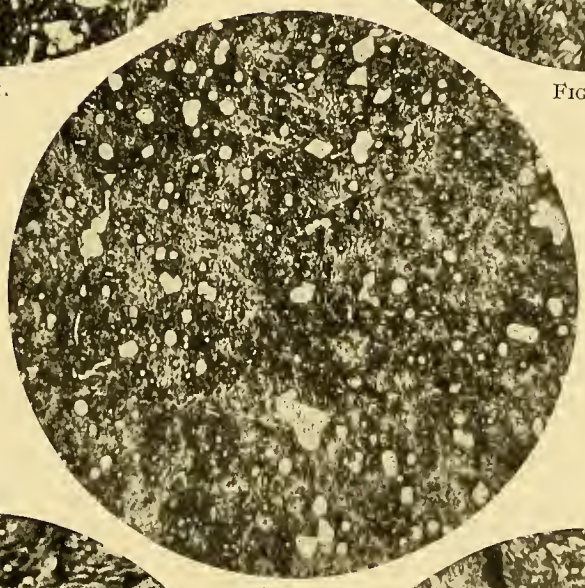


FIG. 3.

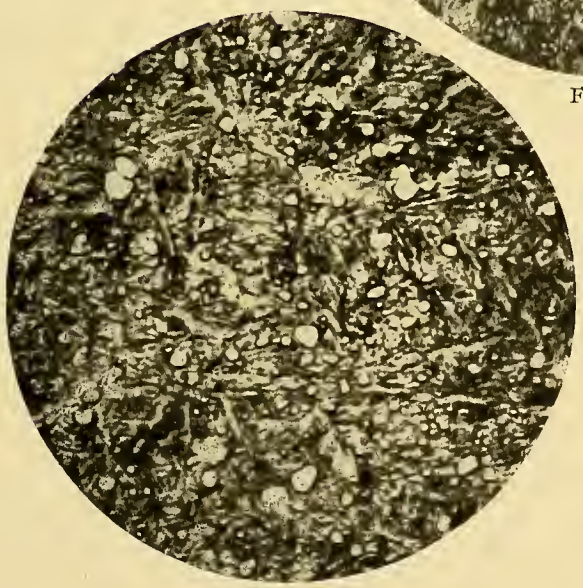


FIG. 4.

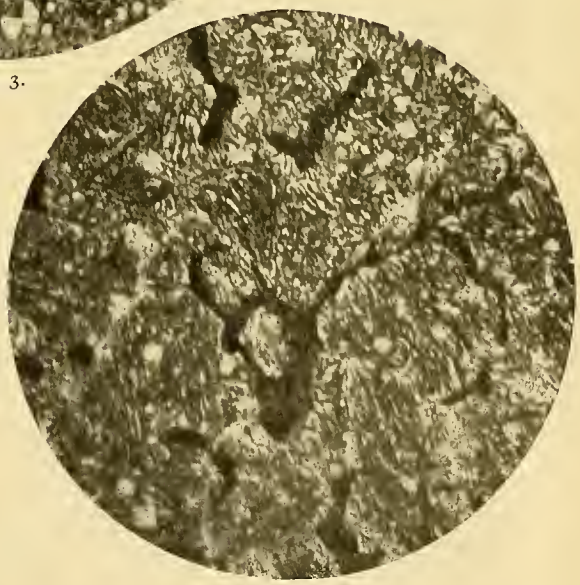
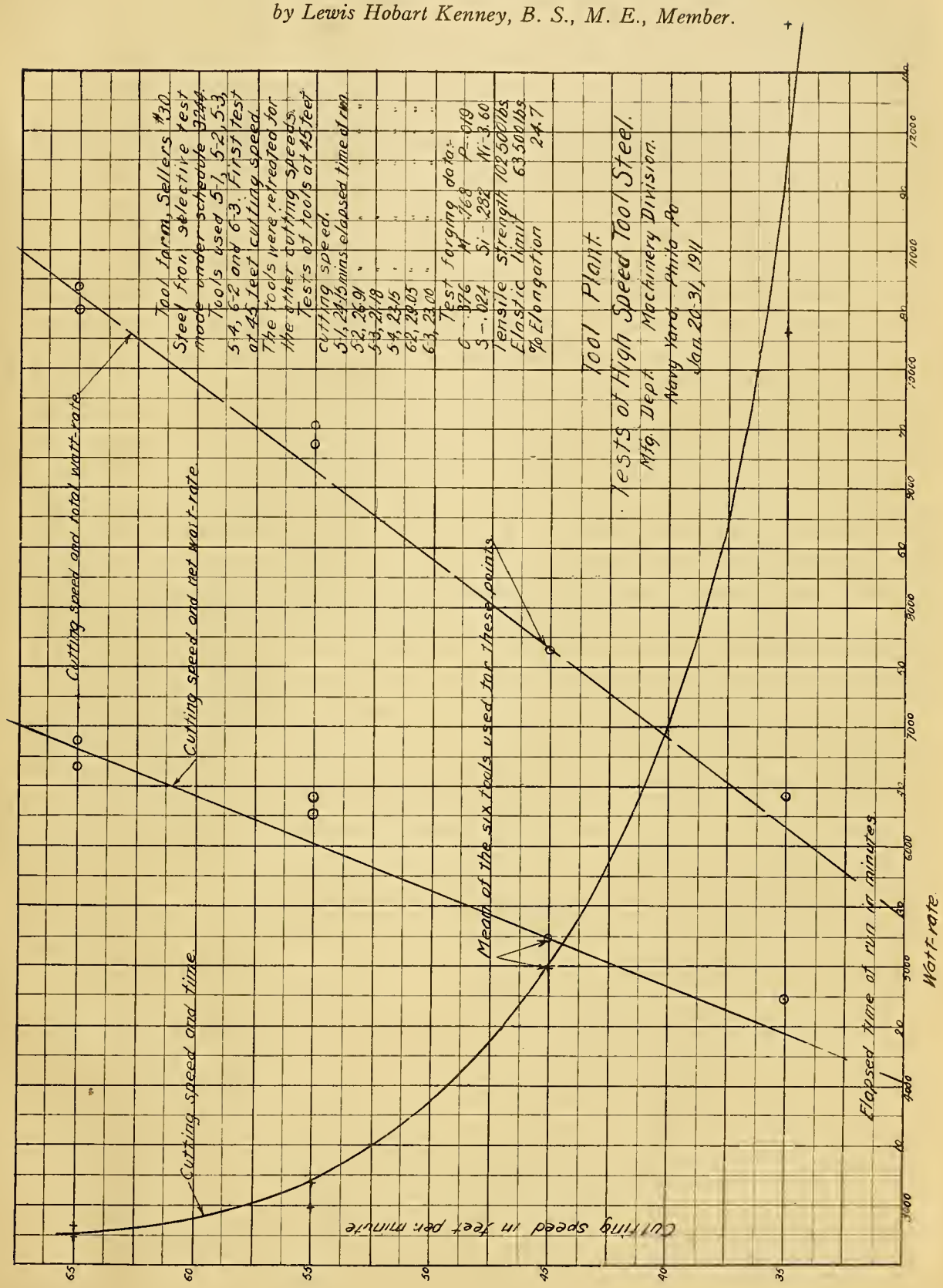


FIG. 5

FIG. 1—CARD NO. 4, B–2, FROM TOOL NO. 1–2.
FIG. 2—CARD NO. 4, B–2, FROM TOOL NO. 3–2.
FIG. 3—CARD NO. 5, A–3, FROM TOOL NO. 4–3.
FIG. 4—CARD NO. 6, B–3, FROM TOOL NO. 1–3.
FIG. 5—CARD NO. 8, B–4, FROM TOOL NO. 2–4.

PHOTOMICROGRAPHS OF SELECTIVE TEST TOOLS, 550X TUNGSTEN TOOL STEEL, CLASS 1, SCHEDULE 4469.

To illustrate paper on "Tool Steel for the U. S. Navy," by Lewis Hobart Kenney, B. S., M. E., Member.



To illustrate paper on "Tool Steel for the U. S. Navy,"
by Lewis Hobart Kenney, B. S., M. E., Member.

Plate 141

Steel	Specification	As per Schedule 3244																																							
	Furnished by	[redacted]																																							
	Tool Number	1-1	1-2	1-4	2-1	2-2	2-3	3-1	3-2	3-4	4-1	4-3	4-5	5-1	5-3	5-5	6-1	6-2	6-3	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3	4-1	4-2	4-3	5-1	5-3	5-2	5-4	6-2	6-3
Cutting Observations	Elapsed Time of Run in Minutes. 1st Grinding	15.82	22.73	22.00	10.77	8.58	8.00	8.05	9.88	11.12	14.15	14.79	13.07	24.16	21.16	36.62	21.95	29.05	23.00	18.68	14.19	12.43	15.42	7.21	10.60	15.59	15.65	18.31	14.85	15.31	10.56	78.50	104.06	48.7	68.4	23.4	30.7
	1st Regrinding	13.16	17.51	11.55	12.60	18.03	11.25	8.85	6.55	7.66	21.40	11.69	13.19	13.02	11.32	19.42	16.85	24.57	14.75	9.56	15.78	18.86	18.46	7.32	10.07	20.66	14.00	28.00	13.02	14.88	11.84	---	---	---	---	---	---
	2nd Regrinding	15.25	10.73	10.85	7.75	5.84	7.42	5.85	6.17	2.80	20.46	15.51	15.35	17.65	25.55	27.03	15.30	21.32	17.82	[illegible]	14.17	18.30	15.04	11.04	7.62	11.91	22.96	11.11	23.40	16.22	14.54	---	---	---	---	---	---
	Mean	14.74	16.99	14.80	10.37	10.82	8.89	7.58	7.53	7.19	18.67	14.00	13.87	18.27	19.35	27.69	18.03	24.98	18.57	12.65	14.71	15.20	15.31	8.52	9.42	16.05	18.19	19.14	17.09	15.47	12.31	---	---	---	---	---	---
	Arithmetical Mean	15.51			10.03			7.43			15.51			21.77			20.51			14.19			11.09			17.79			14.95			91.28		5.86		2.71	
	Speed, Feet per Min. 1st Grinding	45	46	46	45	46	46	45	45	45	46	45	45	45	45	45	45	45	45	44	45	45	45	45	45	45	45	45	45	45	45	35	35	55	55	65	65
	1st Regrinding	45	45	46	46	46	44	46	46	46	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	---	---	---	---	---	---
	2nd Regrinding	46	46	46	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	---	---	---	---	---	---
	Mean	45.3	45.6	46	45.3	45.6	45	45.3	45.3	45.3	45.3	45	45	45	45	45	45	45	45	44.6	45	45	45	45	45	45	45	45	45	45	45	---	---	---	---	---	---
	Arithmetical Mean	45.6			45.3			45.3			45.1			45			45			44.9			45			45			45			35		55		65	
	Cut Inches. Depth of	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4
	Feed of	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
	Ratio of elapsed times of runs. Numerator 20.51	1.320			2.040			2.760			1.320			.943			1.000			1.450			1.850			1.150			1.370			----		----		----	
	Denominator 20.51	.756			.489			.363			.756			1.060			1.000			.692			.540			.867			.729			----		----		----	
Electrical Observations	Volts Mean	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238
	Amperes. Friction	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	7		13		16	
	1st Grinding	30-33	31-33	31-33	33-35	31-33	31-33	33-35	30-32	29-31	30-32	30-32	28-30	33-35	33-35	28-30	31-33	29-31	32-34	29-32	29-31	30-32	30-32	31-33	30-32	30-32	31-33	31-33	29-31	30-32	30-32	26-28	26-28	39-41	38-40	44-46	43-45
	1st Regrinding	29-31	32-35	32-35	28-31	31-33	31-33	32-34	32-34	28-30	30-33	28-30	31-33	32-33	31-32	30-32	29-31	29-31	30-32	31-33	30-32	29-31	31-33	30-32	31-33	30-32	30-32	30-32	32-34	30-32	30-32	---	---	---	---	---	---
	2nd Regrinding	29-31	31-33	30-33	30-33	29-31	29-31	32-34	31-33	31-33	30-32	30-32	31-33	31-34	28-30	29-31	30-32	30-32	30-32	30-32	30-32	31-33	31-33	31-33	30-32	32-34	32-34	31-33	31-33	30-32	32-34	---	---	---	---	---	---
	Mean	30.50	32.50	32.30	31.70	31.3	31.3	33.3	32	30.3	31.1	30.3	31	33	31.5	30	31	30.3	31.7	31.1	30.7	31	31.7	31.7	31.3	31.7	32	31.7	31.7	31	31.5	---	---	---	---	---	---
	Arithmetical Mean	31.8			31.4			31.9			30.8			31.5			31			30.9			31.6			31.8			31.5			27		29.5		44.5	
	Watt Rate. Total	7568			7478			7594			7330			7498			7380			7356			7522			7568			7498			6426		7401		10591	
	Friction	2380			2380			2380			2380			2380			2380			2380			2380			2380			2380			1666		3094		3808	
	Net	5188			5098			5214			4950			5118			5000			4976			5142			5188			5118			4760		4307		6793	
Hardness Observations	Scleroscope Test. Point 1	74	75	65	68	75	71	72	73	76	68	74	72	64	78	75	75	78	80	74	72	72	76	75	72	72	72	71	75	75	75	---	---	---	---	---	---
	Point 2	79	76	72	72	74	73	77	77	77	74	74	74	78	84	79	80	78	79	75	72	72	74	74	75	70	69	68	73	72	72	---	---	---	---	---	---
	Point 3	78	77	73	75	74	76	78	79	81	76	76	77	82	65	79	84	84	84	78	75	74	75	75	76	75	73	70	78	78	78	---	---	---	---	---	---
	Point 4	82	88	84	88	84	82	86	86	88	74	84	86	84	84	90	89	84	88	82	77	77	82	82	80	78	74	74	82	82	82	---	---	---	---	---	---
Furnace Observations	Treatment	—												—		1st	Treatment	—														—		Retreatment		—	
	Elapsed Time in High Heat	---	---	---	1.71	1.86	1.68	1.65	1.90	1.52	1.75	---	1.70	1.68	1.68	1.68	---	1.65	1.68	2.13	1.90	2.08	2.13	1.93	1.89	1.88	2.09	1.71	2.20	2.22	2.30	2.60	1.65	1.69	1.94	2.11	1.99
	Temp. in °F. Pre-Heat °F	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
	High Heat °F	2675	2675	2675	2675	2675	2675	2675	2675	2675	2675	2675	2675	2675	2675	2675	2675	2675	2675	2575	2600	2560	2710	2710	2710	2710	2660	2710	2675	2675	2675	2675	2660	2660	2625	2615	2600
Price Deductions	Price per Pound, Cents.	42			36			41.75			55			58			45			45			42			45			44			-----					
	Ratio, (Elapsed Time of Run in Minutes) ÷ Price per Pound.	.369			.278			.178			.282			.375			.456			.316			.264			.396			.340			-----					
	Ratio of Above Ratios. Numerator 4.56	1.240			1.640			2.560			1.620			1.220			1.000			1.440			1.730			1.150			1.340			-----					
	Denominator 4.56	.809			.609			.390			.619			.823			1.000			.693			.579			.868			.746			-----					
	Ratio of Price per Pound. Numerator 45	1.070			1.250			1.080			.818			.776			1.000			1.000			1.070			1.000			1.020			-----					
	Denominator 45	.933			.800			.928			1.220			1.290			1.000			1.000			.933			1.000			.978			-----					
	Relative value in Cents per Pound. 45/Ratio x (Elapsed Time of Run in Minutes)	3.41			2.21			16.3			34.1			47.7			45			31.2			24.3			39.0			32.8			-----					
	20.51 x (Price per lb / Elapsed Time of Run in Minutes)	55.5			73.5			111.51			72.6			54.6			45			65.0			77.7			51.8			60.4			-----					

Notes.—

Pyrometer corrections :- Pre-Heat +200° High Heat −325°

Test of high speed tool steels:- to select material for the U.S. Naval Academy under Schedule 3244, to compare steel furnished under specification 47-5-5, and to secure data for a curve of cutting speed and elapsed time of runs in minutes. All tools were run until ruined and no lubricant or cutting compound was used.

—Specified Chemical Composition of High Speed Steel.—

	Carbon	Chromium	Manganese	Phosphorus	Silicon	Sulphur	Tungsten	Vanadium
Sched 3244.	.55 to .75	3.00 to 6.00	.00 to .20	.00 to .02	.00 to .25	.00 to .02	16.00 to 20.00	.00 to 1.00
47-5-5	.55 - .75	5.25 - 6.00	.00 - .15	.00 - .02	.00 - .11	.00 - .02	18.50 - 19.50	.10 - .35

—Explanation of Computations.—

"Ratio of elapsed times of runs"

Upper line = $\frac{\text{Arithmetical mean of elapsed times of runs at tools 6-1, 6-2, 6-3} = (20.51)}{\text{Arithmetical mean of elapsed times of runs of other tools.}}$

Lower line = $\frac{\text{Arithmetical mean of elapsed times of runs of other tools}}{\text{Arithmetical mean of elapsed times of runs at tools 6-1, 6-2, 6-3} = (20.51)}$

"Ratio of above ratios"

Upper line = $\frac{\text{Ratio of tools 6-1, 6-2, 6-3} = (4.56)}{\text{Ratio of other tools.}}$

Lower line = $\frac{\text{Ratio of other tools}}{\text{Ratio of tools 6-1, 6-2, 6-3} = (4.56)}$

"Ratio of price per lb"

Upper line = $\frac{\text{Price of tools 6-1, 6-2, 6-3 per lb} = (.45)}{\text{Price of other tools per lb}}$

Lower line = $\frac{\text{Price of other tools per lb}}{\text{Price of tools 6-1, 6-2, 6-3 per lb} = (.45)}$

"Relative value in cents per pound"

The upper line in table shows the relative value in cents per pound of other tools compared with "price per pound, cents" of tools 6-1, 6-2, 6-3.

$= \frac{\text{Price of tools 6-1, 6-2, 6-3 per lb cts} \times \text{Arith. mean of elapsed times of runs in min. of other tools}}{\text{Arithmetical mean of elapsed times of runs in min. of tools 6-1, 6-2, 6-3.}}$

The lower line in table shows the relative value in cents per pound of tools 6-1, 6-2, 6-3, compared with "price per pound, cents" of other tools.

$= \frac{\text{Price of other tools per lb cts} \times \text{Arith. mean of elapsed times of runs in min. of tools 6-1, 6-2, 6-3}}{\text{Arithmetical mean of elapsed times of runs in min of other tools}}$

Respectfully submitted,
Lewis H. Kenney, B.S. M.E.

TOOL PLANT.
TEST OF HIGH SPEED TOOL STEEL.

MACHINERY DIVISION.
NAVY YARD, PHILADELPHIA, PA.
SCALE ---------- 1 FOOT
DATE ---------- Feb. 10, 1911.
DRAWN BY ---------- W.V.A.
TRACED BY ---------- M.F.
CHECKED BY ---------- L.H.K.
EXAMINED ----------
ASSISTANT IN CHARGE ----------
LIEUT. COMMANDER U.S.N.
FOR ENGINEER OFFICER.
SHEET NUMBER 607

To illustrate paper on "Tool Steel for the U. S. Navy,"
by Lewis Hobart Kenney, B. S., M. E., Member

Tungsten Tool Steel Class 1

Bidders Index Number | Name of Bidder and Steel | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8

Furnace Observations | Mechanical Test | Electrical Observations | Cutting Tests | Time Observations

Chemical Analysis

Index	Bidders Index Number	1	2	3	4	5	6	7	8
Trade Name									
Carbon	%								
Chromium	%								
Manganese	%								
Phosphorus	%								
Silicon	%								
Sulphur	%								
Tungsten	%								
Vanadium	%								
Iron	%								
As per specification									
Furnace temperature									
Quenched in water									
Drawn down to red temp.									
Revolutions per minute of lathe									
Depth of cut inches									
Feed inches per revolution									
Time of first cut									
Time of second cut									
Time of third cut									
Time of fourth cut									
Time of fifth cut									
Time of sixth cut									
Time of seventh cut									
Time of eighth cut									
Total time of run									
Price per pound cents									
S. Selective factor		3327	6301	5982	8594	4412	4878	6197	4135

Carbon Tool Steel Class 1

Index	Bidders Index Number	1	3	4	5	6	7
Trade Name							
Carbon	%						
Chromium	%						
Manganese	%						
Phosphorus	%						
Silicon	%						
Sulphur	%						
Tungsten	%						
Vanadium	%						
Iron	%						
As per specification							
Furnace temperature							
Quenched in water							
Drawn down to red temp.							
Revolutions per minute of lathe							
Depth of cut inches							
Feed inches per revolution							
Time of first cut							
Time of second cut							
Time of third cut							
Time of fourth cut							
Time of fifth cut							
Time of sixth cut							
Time of seventh cut							
Time of eighth cut							
Total time of run							
Price per pound cents							
S. Selective factor							

Carbon Tool Steel Class 2

Index	Bidders Index Number	1	3	4	5	6	7
Trade Name							
Carbon	%						
Chromium	%						
Manganese	%						
Phosphorus	%						
Silicon	%						
Sulphur	%						
Tungsten	%						
Vanadium	%						
Iron	%						
As per specification							
Furnace temperature							
Quenched in water							
Drawn down to red temp.							
Revolutions per minute of lathe							
Depth of cut inches							
Feed inches per revolution							
Time of first cut							
Time of second cut							
Time of third cut							
Time of fourth cut							
Time of fifth cut							
Time of sixth cut							
Time of seventh cut							
Time of eighth cut							
Total time of run							
Price per pound cents							
S. Selective factor							

Carbon Tool Steel Class 3

Index	Bidders Index Number	1	3	4	5	6	7
Trade Name							
Carbon	%						
Chromium	%						
Manganese	%						
Phosphorus	%						
Silicon	%						
Sulphur	%						
Tungsten	%						
Vanadium	%						
Iron	%						
As per specification							
Furnace temperature							
Quenched in water							
Drawn down to red temp.							
Revolutions per minute of lathe							
Depth of cut inches							
Feed inches per revolution							
Time of first cut							
Time of second cut							
Time of third cut							
Time of fourth cut							
Time of fifth cut							
Time of sixth cut							
Time of seventh cut							
Time of eighth cut							
Total time of run							
Price per pound cents							
S. Selective factor							

Carbon Tool Steel Class 4

Index	Bidders Index Number	1	3	4	5	7
Trade Name						
Carbon	%					
Chromium	%					
Manganese	%					
Phosphorus	%					
Silicon	%					
Sulphur	%					
Vanadium	%					
Iron	%					
As per specification						
Furnace temperature						
Quenched in water						
Drawn down to red temp.						
Time of first cut						
Time of second cut						
Total time of run						
Price per pound cents						
S. Selective factor						

Identification Table

Index	Name of Bidder	Tungsten Class 1	Carbon Class 1	Carbon Class 2	Carbon Class 3	Carbon Class 4
		Trade name of tool steels				
1						
2						
3						
4						
5						
6						
7						
8						

Explanation of Test

Kind of Tool Steel	Description of Tool	Lubricant	Condition of Tool at End of Run	Adjustment of Observations	Basis of Absolute Comparison	Price, cents per pound	Selective Factor	Relative Value	Kind of Tool Steel
Tungsten Class 1	Cutting Lathe Tool Form #20	None	Ruined	Means at least squares, according to Hartman, for a 30 min time of run	None				Tungsten Class 1
Carbon Class 1	An adjustable cutting gauge as given by Mr. A. S. Dickinson in Transactions of American Soc. of M.E.	None	Broken in shank or teeth	None	None		Price of Basis of Absolute Comparison × Price per pound		Carbon Class 1
Carbon Class 2	Ship plate	None	Broken in shank or teeth	None	Z = Mean elapsed time of run		Price of Basis of Absolute Comparison × Price per pound		Carbon Class 2
Carbon Class 3	Plate steel pipe press ed	Oil	Broken or cutting edge faced	Two poorest rejected	Z = Mean distance tool cut		Price of Basis of Absolute Comparison × Price per pound		Carbon Class 3
Carbon Class 4	3 "x 4" x 12 ft	None	Not ruined	None	Condition of tool at end of run		Condition of tool at end of run		Carbon Class 4

Notes: Specifications, displaying some that failure of a bidder to furnish samples to Gaining Stress Tester at very time, following on the of or before the time set for opening bids would be — now back but from consideration. Respectfully, the report includes only those results which are not in the notes above.

The report gives the formal analysis of the samples "together" with the date and description of the test and the method of testing in the "relative factor." The "highest" selective factor determines the relative manufacture of each of the contracts.

The test steels having the highest selective factor are the best steels on the identification table.

It will be noted that the chemical composition of those tool steels being the highest selective factor, are not called "best" respectfully submitted

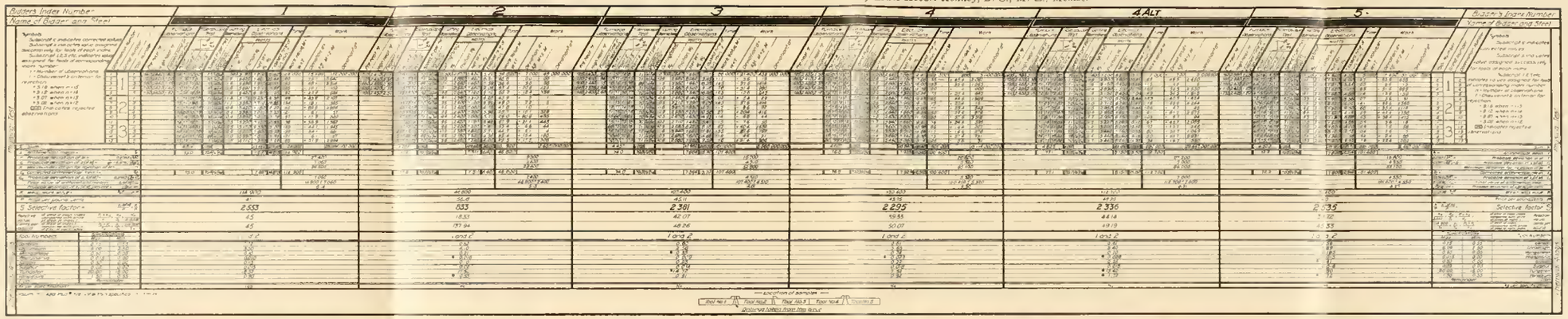
Lewis H. Kenney, B.S., M.E.

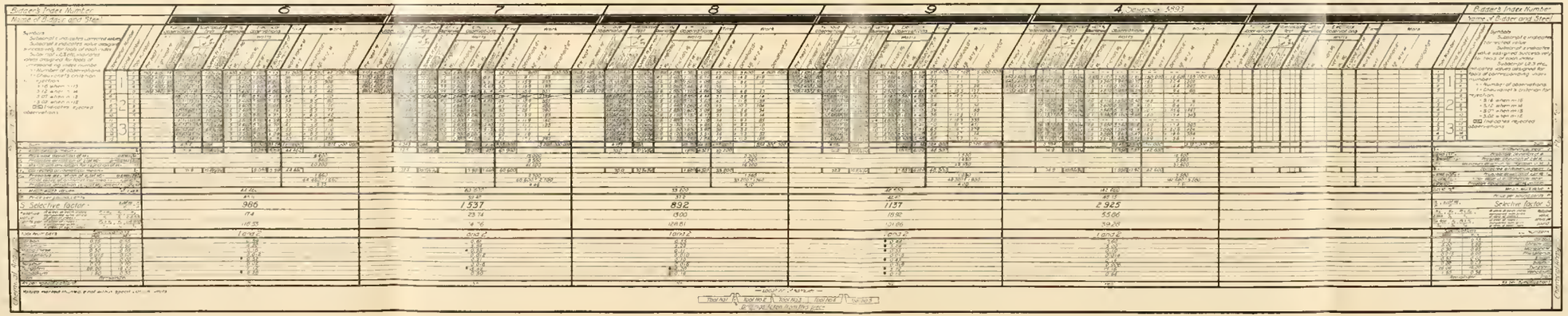
EASTERN NAVY YARDS.
TEST OF TOOL STEELS
UNDER SCHEDULE 3853

MACHINERY DIVISION
NAVY DEPARTMENT

SHEET NUMBER 1058

To illustrate paper on "Tool Steel for the U. S. Navy,"
by Lewis Hobart Kenney, B. S., M. E., Member





| Material on Which Tools Were Tested | | |

To illustrate paper on "Tool Steel for the U. S. Navy,"
by Lewis Hobart Kenney, B. S., M. E., Member

Class 1

Bidder's Index Number	1	1A	2	3	4	5	6	7	9
Name of Bidder									
Name of Steel									
Physical Test									
5. Selective factor	0.22	0.43	0.90	0.58	1.37	2.85	0.97	2.85	0.32
Relative Value	81	4.97	9.35	4.19	11.50		8.59		4.91
Carbon Steels	1.58	38.61	23.15	27.14	11.50		16.23		28.21
Tungsten Steels								10.43	3.19
Relative Value								9.50	82.81
Tungsten Steels	1.08	1.04	5.50	1.99	5.40		4.08	10.43	3.19
Relative Value	10.43	16.63	5.74	11.33	16.34		9.52	9.50	82.81
Body Numbers	All	All	All	All	All		All	All	All
Relative Value									2.82
Carbon	0.33	0.38	0.41	0.33	0.41		0.33	0.30	0.31
Manganese	0.33	0.29	0.22	0.33	0.41		0.33	0.30	0.31
Phosphorus	0.02	0.02	0.02	0.02	0.02		0.02	0.02	0.02
Silicon	0.02	0.02	0.11	0.18	0.24		0.12	0.11	0.06
Sulphur	0.02	0.02	0.02	0.01	0.018		0.03	0.02	0.02
Vanadium	Optional							0.34	0.23
Tungsten	2.00	2.00							
As per specification?	No	Yes	No	No	Yes		Yes	No	No

Class 2

Bidder's Index Number	1	1A	2	3	4	5	7	9
Name of Bidder								
Name of Steel								
Physical Test								
5. Selective factor	108	1.42	0.62	0.12	0.61	0.79	2.98	0.68
Relative Value	8.57	13.50	8.43	5.07	4.23	3.09		4.91
Carbon Steels	17.78	13.50	30.94	26.64	28.93	26.20		28.21
Tungsten Steels							9.55	
Relative Value							9.55	
Tungsten Steels	4.08	4.83	3.08	2.41	2.08	4.83	9.55	2.81
Relative Value	28.36	10.05	42.92	19.54	44.49	36.04	9.55	8.87
Body Numbers	All	All	All	All	All	All	All	All
Relative Value							2.85	2.36
Carbon	0.41	0.41	0.33	0.33	0.34	0.33	0.30	0.31
Manganese	0.41	0.41	0.33	0.33	0.34	0.34	0.30	0.23
Phosphorus	0.02	0.02	0.02	0.008	0.006	0.01	0.02	0.021
Silicon	0.24	0.20	0.18	0.14	0.10	0.11	0.12	0.083
Sulphur	0.03	0.03	0.03	0.03	0.024	0.019	0.03	0.026
Vanadium	Optional							
Tungsten							2.28	
As per specification?	Yes	Yes	No	No	Yes	Yes	No	No

Explanation of Tests

Class Number	1	2	3	4
Water on whole face in the Tester	1 Quarts	1 Pint	Half Pint	1 Pint
Depth of Water	48 800 pounds per square inch	48 800 pounds per square inch	48 800 pounds per square inch	48 800 pounds per square inch
Diameter of Tool	0.480	0.480	0.480	—
Depth of Groove	0.500	0.500	0.500	—
Width of Groove	0.500	0.500	0.500	—
Description of Tool	Adjustable at any angle as given by Bidder. Designed with respective angle. No grind	Same Tool	Same Tool	Same Tool
Condition of Tool at Beginning of Test	None	None	None	None
Condition of Tool at End of Test	Broken in chunks or teeth	Broken in chunks or teeth	Broken in chunks or teeth	Not marked
Adjustment of Tool at Beginning of Test	None	None	Observation was not noted that the tool was not adjusted	None
Basis of Absolute Comparison	Three-quarter hour time	Three-quarter hour time	Three-quarter hour time	None
Price per pound	Price quoted per pound where a uniform price per pound is given. Price price quoted divided by total weight where two or more			
Selective Factor	Ratio of Basis of Absolute Comparison to price per pound			None
Relative Value	Value 1 cents per pound of material of each index compared with quoted price of material of each local highest selective factor. Value of material of index having highest selective factor compared with quoted price of material of each index			None computed
Heat-Cooling Curves	Determined by Recalescent Tester			

Class 3

Bidder's Index Number	1	1A	2	3	4	5	7	9
Name of Bidder								
Name of Steel								
Physical Test								
5. Selective factor	11.17	9.51	4.20	7.18	11.88	7.40	8.36	10.91
Sample from	End of bar	End of bar	End of bar	End of bar	End of bar	End of bar	End of bar	End of bar
Carbon	0.83	0.86	0.86	0.85	0.84		0.85	0.78
Vanadium	Optional	0.34	0.34					
Tungsten	2.00	2.00	2.00	2.00	2.00		2.00	2.00
Phosphorus	0.02	0.02	0.02	0.02	0.02		0.02	0.02
Sulphur	0.03	0.03	0.03	0.03	0.03		0.03	0.03
As per specification?	Yes	No	Yes	No	No	Yes	No	No

Class 4

Bidder's Index Number	1	3	4	5	7	9
Name of Bidder						
Name of Steel						
Physical Test	Condition of tool at end of test					
Surface temperature after quenching in air at 70° Temperature in oil bath to 65°C	Good	Good	Good	Good	Good	Good
	Good	Good	Good	Good	Good	Good
Price per pound cents	0.75	1.48	1.00	0.25	[illegible]	1.00
Tool Numbers	All	All	All	All	All	All
Carbon	0.78	0.90	0.85	0.82	0.93	0.98
Vanadium	Optional					
Manganese	0.38	0.225	0.25	0.34	0.39	0.29
Phosphorus	0.02	0.02	0.014	0.005	0.04	0.018
Silicon	0.13	0.10	0.18	0.15	0.12	0.13
Sulphur	0.04	0.031	0.016	0.03	0.027	0.018
Vanadium	Optional					
Tungsten	Remainder					
As per specification?	No	No	No	No	No	No

Tungsten Tool Steel Class 2

Bidder's Index Number	
Name of Bidder	
Name of Steel	
Physical Test	
Surface temperature after quenching in air at 70° Temperature in oil bath to 65°C	
Price per pound cents	
Tool Numbers	
Carbon	
Vanadium	
Manganese	
Phosphorus	
Silicon	
Sulphur	
Vanadium	
Tungsten	
As per specification?	

Notes

Some Bidders seem to state that failure of a Bidder to comply with all the requirements of the specifications would eliminate such bid from consideration. According to this report, indeed only those tool steels proposed for all tests were eliminated as noted above.

The report gives the total analysis of the samples together with the data and analysis of the test and the method of determining the selective factor. The determination for sample of carbon was determined by the high selective factor for Classes 1, 2 and 3 and by the price per pound, due consideration being given to the union from of the tools and the test for Class 4.

Some of the samples submitted under Classes 1 and 2 contained tungsten although that material was not included in the specifications. Three relative values were computed for samples not containing tungsten to samples containing tungsten and for all samples. A sample of Tungsten Tool Steel Class 2 purchased under specification 4733 of July 01, 1911 was tested under the same conditions prevailing during the selective test for comparison with the above mentioned steel containing tungsten. It will be noted that the time of run of tools containing tungsten, once and the carbon content, consumed tools requirements was much longer than that of tools not containing tungsten.

Respectfully submitted
Lewis H. Kenney B.S., M.E.
Member Society of Naval Architects and Marine Engineers
Member Amer. Soc. Mech. Engs.

SELECTIVE TEST
CARBON TOOL STEELS CLASS 1 2 3 & 4
SCHEDULE 4469

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